Labor market perspectives of the Brazilian sugarcane agro-industry: prospects and challenges

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by

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Now, more than ever, I understand the challenges and complexity of development issues and the expectations of multiple stakeholders and institutions. To all of them:

Muito obrigada!

AFFIDAVIT

I hereby declare that all information disclosed in this thesis is a product of my original and individual work. Neither this work in its complete form, nor any of its parts has been submitted to any university other than the Brandenburg University of Technology for the award of any academic degree. Furthermore, I confirm that all sources other than my own have been duly acknowledged.

Cinthya L. Guerrero

ABBREVIATIONS

ANEEL	Brazilian Electricity Regulatory Agency
BNDES/CGEE	Brazilian Development Bank /Center for Strategic Studies and Management
CONAB	Brazil's National Commission of Agricultural Supply
EMBRAPA	Brazilian Agricultural Research Corporation
EPE	Energy Research Company
FAO	Food and Agriculture Organization of the United Nations
FERAESP	Federation of Salaried Rural Workers of the State of Sao Paulo
IBGE	Brazilian Institute of Geography and Statistics
IEA	International Energy Agency
IEA^2	Agricultural Economics Institute
IPEA	Brazilian Institute for Applied Economic Research
MAPA	Ministry of Agriculture, Livestock and Food Supply
MDA	Ministry of Agrarian Development
MTE	Ministry of Labor and Employment
PNAD	National Household Sample Survey
UNICA	Brazilian Sugarcane Industry Association
USDA	United States Department of Agriculture

UNITS

The metric system is used throughout the text.

^{o}C	degree Celsius
CO_2eq	Carbon dioxide equivalent
ha	Hectare (104 m^2)
tonne	Metric tonne (1,000 kg)
toe	Tonnes of equivalent oil (energy equivalent)
R$	Brazilian Reais

ABSTRACT

Brazil has five centuries of tradition in sugarcane production and is the world's largest producer and exporter of sugar. It is also the world’s largest exporter and the second largest producer of ethanol fuel. Economic, social and environmental aspects have caused structural modifications in the sugarcane production system including the mechanization of the harvesting operation. Mechanization has potential economic, environmental, agronomic and social impacts. From the economic point of view, it leads to cost reductions, and possibly higher productivity. Mechanization could also have a positive impact on the environmental dimension of the sector’s sustainability as it avoids the need for pre-burning practices, a point that is especially relevant for the ethanol supply chain. As mechanization enables the harvesting of raw sugarcane, dry leaves and tops (trash) are left on the field, which could have agronomic advantages. The recovery of a reasonable fraction of the sugarcane trash could potentially increase bioelectricity production. These energy gains could increase the sector’s competitiveness and to some extent avoid emissions from fossil fuels. On the other hand, agricultural mechanization can be considered a controversial agricultural technology as its increased intensity causes a negative balance in rural jobs creation. Mechanization simultaneously causes a demand increase for specialized agricultural workers and reduces the demand for non-specialized workers. Currently, the lack of qualified workforce is a challenge for the sector. In an attempt to bridge this gap, partially coordinated qualification strategies had emerged. Even when a number of additional jobs will be created, presumably the sector will not be able to relocate its current rural staffing. Large portions of these workers are temporary migrants from deprived regions of Brazil who typically have low levels of schooling, including a share of illiterate. Other agricultural products have also shown the tendency to reduce their number of workers, regardless of the increases in their production. This phenomenon, partially caused by increasing mechanization, could also hinder the opportunities of sugarcane harvesters to absorb into other rural activities. In addition, the changes undergone by the sector have been accelerated due to the introduction of environmental laws phasing out the sugarcane burning practice in various federal entities. The complexity of this transition and the remarkable heterogeneity of the sector were approached in this dissertation using the Human Capability Framework. The use of this tool led to the identification of key capacity and labor market influencing features based on stakeholders’ interaction and feedback. The framework was an instrumental part of understanding the multifaceted system of actors and structures, which have a stake in the developments of the sector. The identified capacity influencing features were: workers’ background, workers’ union affiliation, formal and informal skill formation, demographics and productivity. It was noted that key socio-economic indicators vary widely in a regional basis with a sharp substandard trend in the workers from the North and Northeast. The identified labor market influencing features were: national and international markets, legislation, agricultural trends, working conditions, the pace of mechanization, and Agro-environmental Zoning. The labor market is expected to undergo qualitative, quantitative, geographical and temporal changes depending of the interaction of these elements. It was concluded that there is an increasing influence of globalization on the developments of the sector and that these changes will heavily rely on the developments of production, area expansion, productivity, and the technology adopted. It was concluded that if coordinated policies in a number of separate but linked areas and plans for their implementation were developed, then labor supply and demand might be more constructively linked when dealing with economic, energy, and sustainability goals.

ZUSAMMENFASSUNG

Brasilien verfügt über eine fünf Jahrhunderte alte Tradition in der Zuckerrohrproduktion und ist der weltweit größte Produzent und Exporteur von Zucker. Brasilien ist auch der weltweit größte Exporteur und der zweitgrößte Produzent von Ethanol-Kraftstoff. Wirtschaftliche, soziale und ökologische Aspekte haben Veränderungen in der Zuckerrohrproduktion herbeigeführt. Die zunehmende Mechanisierung der Ernte ist ein Beispiel für ihre Interaktionen. Die Mechanisierung hat wirtschaftliche, ökologische, agronomische und sozialen Auswirkungen. Vom wirtschaftlichen Standpunkt aus gesehen, führt sie zu Kostensenkungen und möglicherweise einer höheren Produktivität. Die Mechanisierung könnte auch einen positiven Einfluss auf die ökologische Dimension der Nachhaltigkeit der Branche ausüben, weil es die Notwendigkeit für „Verbrennungspraktiken“, ein Punkt der besonders relevant für die Ethanol-Supply-Chain ist, vermeidet. Durch die Mechanisierung ermöglicht die Ernte des Rohstoffs Zuckerrohr, dass trockene Blätter und Zuckerrohrabfall auf dem Feld gelassen werden können, was agronomische Vorteile haben könnte. Die Erholung ein angemessener Anteil des Zuckerrohrabfalls könnte ein großes Potenzial für Biostrom-Anwendungen aufweisen. Auf der anderen Seite ist die Mechanisierung der Landwirtschaft eine der umstrittensten landwirtschaftliche Technologien, weil die erhöhte Intensität der Mechanisierung einen negativen Saldo für die Schaffung von Arbeitsplätzen auf dem Land verursacht. Bis vor kurzem war die Zuckerrohr Agro-Industrie dafür anerkannt worden, dass sie einen großen Anteil an gering qualifizierten Arbeitskräften absorbieren konnte, weil sie sich stark auf manuelle Arbeit zur Durchführung von arbeitsintensiven Tätigkeiten stützte. Die Mechanisierung bewirkt gleichzeitig eine Erhöhung der Nachfrage für spezialisierte landwirtschaftliche Arbeitnehmer und verringert die Nachfrage nach Nicht-Facharbeitern. Derzeit ist der Mangel an qualifizierten Arbeitskräften eine Herausforderung für die Branche. Auch wenn eine Reihe von zusätzlichen Arbeitsplätzen geschaffen werden, wird die Branche vermutlich nicht in der Lage sein, ihr aktuellen ländlichen Personal selbst weiterzubilden. Dieses Problem gewinnt an Komplexität, wenn man das Profil der Mehrheit dieses Kontingent betrachtet. Ein großer Teil dieser Arbeiter sind temporäre Migranten aus benachteiligten Regionen Brasiliens und / oder haben eine niedrige Schulbildung, einschließlich einem Anteil von Analphabeten. Der zunehmende Mechanisierungstrend von landwirtschaftlichen Produkten wird ihre Chancen auf Annahme von anderen Aktivitäten im ländlichen Raum reduzieren. Darüber hinaus wurden die Änderungen durch den Sektor selbst vollzogen, beispielsweise durch die Einführung von Umweltgesetzen der schrittweise Ausstieg aus der Praxis des Verbrennens von Zuckerrohr in verschiedenen föderalen Einheiten beschleunigt. Die Komplexität dieses Übergangs und die bemerkenswerte Heterogenität des Sektors wurden im durch Einbeziehung des Human Capability Framework als Rahmenmodell menschlicher Fähigkeiten berücksichtigt. Dieses Rahmenmodell führte zur Identifizierung von wichtigen Kapazitäten von durch den Arbeitsmarkt beeinflussten Eigenschaften basierend auf der Interaktion und dem Stakeholder-Feedback. Das Rahmenmodell war ein instrumentaler Teil für das Verständnis des vielschichtigen Systems von Akteuren und Strukturen, die eine Beteiligung an der Entwicklung der Branche haben. Die identifizierten kapazitätsbeeinflussten Merkmale waren: der jeweilige Hintergrund des Arbeiters, die Zugehörigkeit zu einem Syndikat, formale und informelle Bildung, Fähigkeiten, Demografie und Produktivität. Es wurde darauf hingewiesen, dass die wichtigsten sozioökonomischen Indikatoren regional sehr unterschiedlich ausgeprägt sind mit einer starken unterdurchschnittlichen Tendenz bei den Arbeiter aus dem Norden und Nordosten. Die identifizierten den Arbeitsmarkt beeinflussenden Merkmale waren: nationale und internationale Märkte, Gesetzgebung, landwirtschaftliche Trends, Arbeitsbedingungen, Mechanisierungstempo und die Agro-Umwelt-Gebietsaufteilung. Es wird erwartet, dass der Arbeitsmarkt qualitativen, quantitativen, räumlichen und zeitliche Veränderungen in Abhängigkeit der Wechselwirkung zwischen diesen Elementen unterzogen wird. Es wurde gefolgert, dass es einen zunehmenden Einfluss der Globalisierung auf die Entwicklung der Branche gibt und dass diese Veränderungen stark von den Entwicklungen der Produktion, der Expansion des Areals, die Produktivität und die angewendete Technologie abhängen. Es wurde gefolgert, dass wenn koordinierte Politik in einer Reihe von separaten, aber miteinander abgestimmten Bereichen Pläne für deren Umsetzung entwickelt wurden, das Arbeitsangebot und-nachfrage mehr konstruktiv verbunden sein könnte, wenn es um Wirtschafts-, Energie-und Nachhaltigkeitsziele geht.

RESUMO

O Brasil tem cinco séculos de tradição na produção de cana-de-açúcar e é o maior produtor e exportador mundial de açúcar. É também o maior exportador mundial de etanol e o segundo maior produtor. Aspectos econômicos, sociais e ambientais têm causado modificações estruturais no sistema de produção da cana. A crescente mecanização da operação de colheita é um exemplo dessas modificações. A mecanização tem impactos econômicos, ambientais, agronômicos e sociais. Do ponto de vista econômico, leva à redução de custos e a produtividade é possivelmente maior. A mecanização também pode ter um impacto positivo na dimensão ambiental da sustentabilidade do setor, pois evita a necessidade das queimadas, ponto especialmente relevante para a cadeia produtiva do etanol. Como a mecanização permite a colheita da cana crua, as folhas secas e pontas (palha) são deixadas no campo, fator que pode trazer vantagens agronômicas. A recuperação de uma fração razoável da palha pode ter grande potencial para aplicações em bioeletricidade. Estes ganhos energéticos podem aumentar a competitividade do setor e, em certa medida, diminuir as emissões de combustíveis fósseis. Por outro lado, a mecanização agrícola é uma prática das mais controversas, pois provoca um impacto negativo na criação de novos postos de trabalho. A mecanização provoca um aumento na demanda por trabalhadores agrícolas especializados e reduz a demanda por trabalhadores não especializados. Atualmente, a falta de mão-de-obra qualificada é um desafio para o setor. Na tentativa de preencher esta lacuna, estratégias de qualificação parcialmente coordenadas têm emergido. Porém, mesmo com a criação de novos postos de trabalho, presumivelmente, o setor não será capaz de realocar seus trabalhadores atuais. Este problema ganha complexidade quando se considera o perfil da maioria desse contingente. Grande parte destes trabalhadores são migrantes temporários de regiões carentes do Brasil e/ou possuem baixos níveis de escolaridade, e muitos são analfabetos. Somado a isso, outros produtos agrícolas também têm mostrado a tendência de reduzir o seu contingente da força de trabalho, independentemente dos aumentos da sua produção. Este fenômeno, em parte causado pela tendência crescente da mecanização, irá prejudicar a oportunidade destes trabalhadores serem absorvidos por outras atividades rurais. Além disso, as mudanças sofridas pelo setor foram aceleradas devido à introdução de leis ambientais que visam à eliminação gradual da queima da cana em diferentes entidades federais. A complexidade dessa transição e a heterogeneidade do setor foram abordadas através do Human Capability Framework. Sua construção levou à identificação das variáveis chave, influenciando a capacidade do mercado de trabalho, com base na interação e realimentação dos stakeholders. A sua utilização foi uma parte instrumental para a compreensão do sistema multifacetado de atores e estruturas que têm participação no desenvolvimento do setor. As características identificadas com capacidade de influenciar a oferta são: região de origem, a filiação sindical, a educação formal e informal, a demografia e a produtividade. Notou-se que os principais indicadores socioeconômicos variam muito em uma base regional, sendo que, nas regiões Norte e Nordeste, os níveis desses indicadores tendem a ser mais baixos. As variáveis identificadas que afetam o mercado de trabalho foram: os mercados nacionais e internacionais, a legislação, as tendências agrícolas, as condições de trabalho, o ritmo de mecanização e do Zoneamento Agroambiental. O mercado de trabalho deverá sofrer mudanças qualitativas, quantitativas, geográficas e temporais, dependendo da interação entre esses elementos. Concluiu-se que há uma crescente influência da globalização sobre a evolução do setor e que essas mudanças dependem grandemente da evolução da produção, da expansão de área, da produtividade e da tecnologia adotada. Concluiu-se também que se as políticas coordenadas em um número de áreas distintas, mas interligadas, e os planos para sua implementação forem desenvolvidos, a oferta e a demanda podem ser ligadas de forma mais construtiva, a fim de lidar com as metas energéticas, econômicas e sustentáveis.

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Chapter 1

1. Introduction

The objective of the first chapter of this dissertation is to provide an insight into the topic. Sect. 1.1 provides background information and gives an introduction to the problem. Sect. 1.2 describes the overall and specific objectives delimiting the study, establishing its scope. The research questions are also formulated and the expected outcomes are explained in detail. Sect. 1.3 briefly describes the selected methodology and justifies its selection in order to achieve the investigation aims. Sect. 1.4 provides a general picture of the structure of this Ph.D. thesis.

1.1 Background summary

In Brazil the supply chains of sugarcane and its main products, sugar and ethanol, are highly important to the employment and income generation of local economies. About 630 thousand workers were hired for the production of sugarcane in Brazil in 2008. From this total ca. 36% were in Sao Paulo (Moraes et al., 2011). Sugarcane is a labor-intensive culture. Its production demands a large number of workers distributed along its phases with a sharp concentration during the harvest, which accounts for 83% of the working days/men when carried out manually (Gonçalves, 1999).

Traditionally, the manual harvest is done after burning the dry leaves and tops of the sugarcane on standing mature crops. This is an activity that has been practiced for centuries, in order to facilitate more efficient manual harvest, transportation and processing of sugarcane stalks (Galdos et al., 2009). This practice (*queimadas* or *despalha a fogo*) also eliminates debris and reduces the risks of poisonous animals, which complicate the manual harvesting. On the other hand, it releases greenhouse gases (GHG) emissions such as CO_2, CH_4 and N_2O. The particles released into the atmosphere have been associated with health problems affecting surrounding populations and impacts on regional and local climate among other negative environmental consequences (Roseiro & Takayanagui, 2004; Lopes & Ribeiro, 2006; Ribeiro 2008; Silva, 2008).

The in-field burning has been maintained because the manual harvest is not economically feasible without this activity (Galdos et al., 2009; Moraes, 2007). The harvesting cost represents more than 50% of the total sugarcane production cost when it is cut for the first time, more than 45% of the second cut, more than 40% of the third cut and ca. 40% of the fourth and fifth cut (Graziano, 2011). Within this context, the harvesting operation is a strategic topic from social, environmental and economic viewpoints.

The sugarcane agro-industry in Brazil was recognized in the past for its capacity to absorb a substantial amount of workers with low levels of formal education (Moraes, 2011). Mechanization will cause a reduction in this workforce demand vis-à-vis manual harvest.

Sugarcane manual harvesting jobs have often been considered as precarious and associated with poor working conditions even when there has been a positive evolution of the job quality and real increases in the earnings of the workers over the years (Basaldi, 2007). Mechanization will reduce the demand for unqualified workers that, as will be depicted in this research work, have usually just a few years of education (and low probability of being absorbed into other sectors of the labor market) and in large proportion are migrants coming from deprived regions of the country.

On the other hand, mechanization leads to changes in the rural workforce profile demanded by the sector. The new occupations required for mechanized operations will need medium to high qualification and specific skills to operate the machinery (Liboni, 2009). Consequently, qualification efforts are going to be crucial in order to guarantee the feasibility of this transition. In general, more specialized occupations are associated with higher remuneration (Fredo, 2011). Furthermore, the occupations associated with mechanization are less physically demanding than the manual sugarcane harvest.

However, Brazilian enterprises in general are facing a lack of qualified workforce. According to the National Industry Confederation, the lack of a qualified workforce affects 69% of the Brazilian enterprises (CNI, 2011). This issue gains complexity as the time frame foreseen for this transition is considered.

The Brazilian Government had gradually established laws banning the pre-burning practice. Mechanical harvesters enable the collection of raw sugarcane. In order to comply with this legislation the pace of mechanization has accelerated. In addition, in Sao Paulo for instance, the “Agro-environmental Protocol” establishes the commitment of the Government of Sao Paulo, the Ministries of Environment and Agriculture and the Association of the Sugarcane Agro-industry of Sao Paulo (UNICA) to eliminate sugarcane burning by 2014 for areas where mechanical harvesting is possible with state of the art harvesters (slope lower than 12%) and by 2017 for areas where mechanical harvesting is not possible (slope higher than 12%) (UNICA, 2011). Hence, for the industries taking part in the protocol, the deadlines established by the Brazilian legislation have been anticipated.

The elimination of the pre-burning practice could enable the recovery of a reasonable fraction of the total amount of tops and leaves (sugarcane trash). When processed with efficient power technologies, the sugarcane trash could have a large potential for bioelectricity applications

(UNICA, 2011). Moreover, the harvest of raw sugarcane permits the maintenance of the dry leaves and tops on the field in a system called green cane management which has impacts on yield, fertilizer management and soil organic matter dynamics (Galdos et al. 2010). This system could have agronomic advantages and disadvantages depending on how it is carried out.

In summary, the mechanization of the sugarcane harvest in Brazil will lead to deep transformations in the sector since this transition has major social, economic, environmental, technological and agronomic implications. It should also be considered as an inexorable process that will raise risks and opportunities. When identified timely, they could increase the probabilities of a sustainable transition.

1.2 Research objectives

The core topic of this dissertation is to study the labor market dynamics in the Brazilian sugarcane agro-industry. Its main objectives are:

- To assess the trends, appraise the perspectives and identify the risks and opportunities of the labor market of the sugarcane agro-industry induced by the mechanization of the harvesting operation in Brazil.
- To approach the role of various interest groups at local and regional levels in order to build a picture of the system of actors and structures which have a stake in the agro-industry developments.

The main research questions of this Ph.D. thesis are:

- How could the new dynamics of the supply and demand of labor in the Brazilian sugarcane agro-industry be more constructively linked to economy and energy-related goals in addition to the application of sustainability principles?
- To what extent could an analysis framework address the complexity of this transition? And how suitable would it be to integrate the points of view from the social actors involved?

The socio-economic transformations undergone by the stakeholders embedded in the production of sugarcane have an undisputable relevance to the development of a theoretical-conceptual framework of the study subject. Nevertheless, they are only one part of the setting. As mentioned before, the mechanization of the harvesting operation will also have implications in the technical, environmental, agronomic and political spheres of the sector. This topic gains complementary importance when studied as part of the sustainability dimensions of the ethanol fuel.

This complex problematic has been addressed taking a wide spectrum of elements and social actors into consideration in order to come up with concrete proposals aimed at sustainability within the intersection of various fields.

1.3 Methodology

In order to attain the research objectives of this dissertation, the activities were organized as follows:

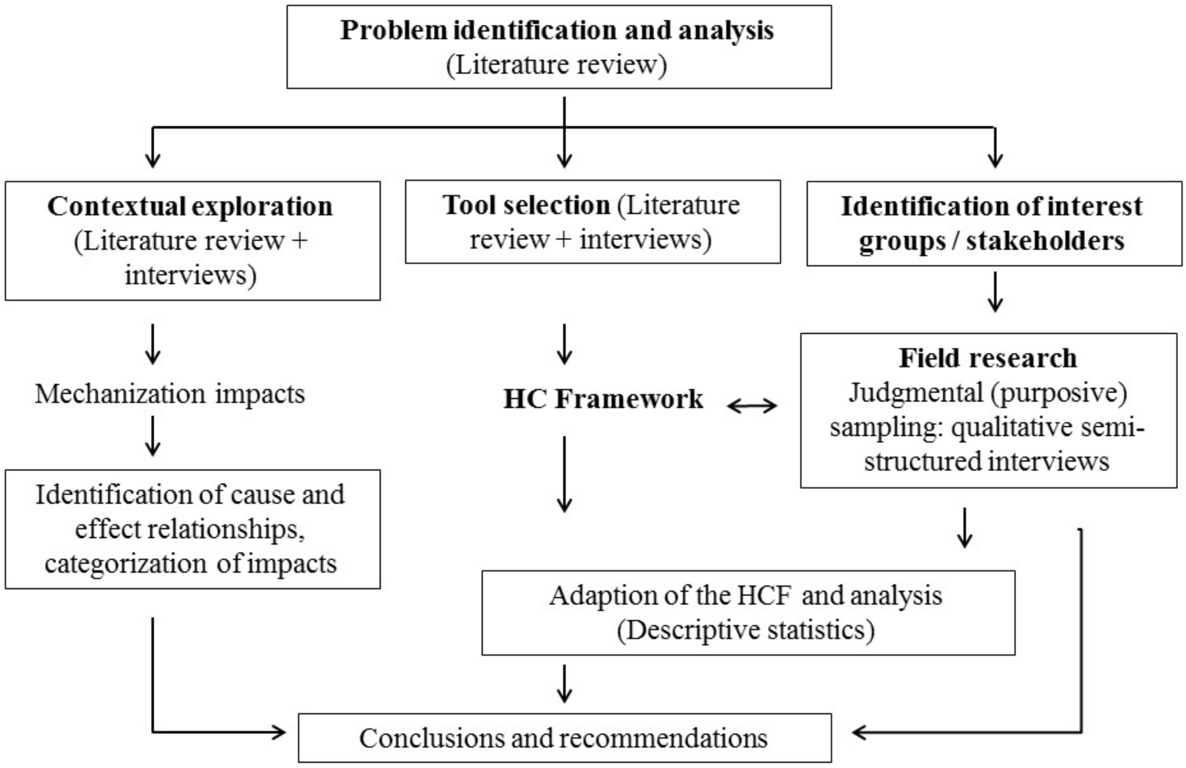

Fig. 1: Methodology

The Human Capability Framework (HCF) provides an integrated view of key economic and social objectives and the role of the labor market in achieving them (NZDL, 1999). The framework "provides a holistic and integrated view of key aspects of the supply (capacity) and demand (opportunity) sides of an industry's labor market by the identification of the influencing factors of their developments" (Tipples, 2004). An additional motivation for selecting the HCF as research tool was its importance as a key guide for public policy design (Tipples, 2004). The framework is expected to provide a robust analytical framework for decision-making. Its three components are capacity, opportunity and matching: "capacity" refers to what people are able to do, "opportunity" refers to the options available for people to get financial or personal reward by using their capacity, and "matching" refers to the process of matching capacity and opportunity (Fig. 2). This research work attempts to prove the suitability of the Human Capability Framework as a method for labor market analysis with the innovation of using it to assess the stakeholders' interaction and feedback. Another innovation was the adaptation of the "matching"element as it was used as the basis for the contruction of a feedback loop diagram.

As will be noted in Chapter 4, this framework proposes various influencing elements for each one of the components encompassed. Nevertheless, in order to construct a framework adapted to this specific case study, these elements were used as a base to be compared to the ones proposed by the social actors interviewed. In this way, it was possible to know if their demands and points of view were covered, or at least partially covered by the framework.

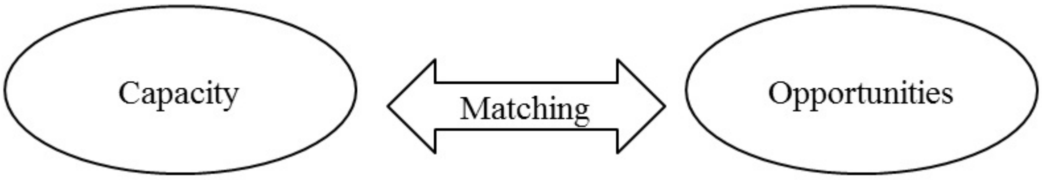

Fig. 2: Simple version of the Human Capability Framework
Source: NZDL, 1999

The literature review and the exploration of the contextual framework shaped further research and enabled the identification of key social actors, which were targeted as potential interview candidates. Structured and semi-structured qualitative interviews were carried out with (for the rural workers) and without (for the industry, governmental and scientific stakeholders) the help of an interview guide. The interviews were transcribed in Portuguese language and authorized by each of the stakeholders involved. The assessment and integration of diverse points of view of the stakeholders helped to better understand their concerns. This facilitated insight into the specific roles that they could play in the implementation of solutions.

The subsequent step was the construction and analysis of an adapted framework. The influencing elements were defined. After having analyzed all of them, it was possible to identify cause and effects relationships to construct a feedback loop diagram. This diagram and the conclusions of the capacity and opportunity side of the framework made possible the development of conclusions and recommendations.

1.4 Structure of the dissertation

This dissertation is structured in a way that each chapter could be read independently (Fig. 3).

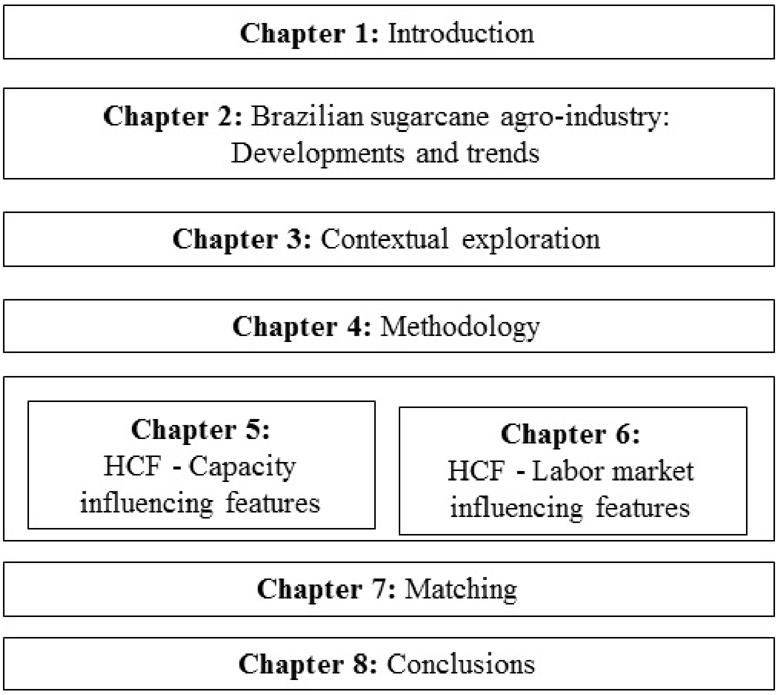

Fig. 3: Structure of the thesis

Chapter 2 gives a picture of specific features of the Brazilian sugarcane agro-industry, focusing on its importance for the generation of energy.

Chapter 3 explores the economic, social, environmental and agronomic implications of the mechanization of the sugarcane harvesting operation and the complexity of their interactions. This chapter includes a cause and effect diagram portraying these impacts and the general analysis that led to its construction.

Chapter 4 reviews the methodology used for this dissertation. The Human Capability Framework is described in more detail. The analysis that led to the stakeholder identification is described. An overview of the fieldwork carried out is delivered. Based on these inputs the chapter includes the construction of a HCF adapted to the Brazilian context.

Chapter 5 analyzes the elements that influence the capacity side of the framework constructed. The chapter includes conclusion remarks about the worker's profile.

Chapter 6 analyzes the elements that influence the opportunity side of the framework constructed. The developments influencing the labor market perspectives in the sector are systematically reviewed. The chapter includes concluding remarks about the labor market's profile.

Chapter 7 matches the demand and the supply sides of the framework by exploring the direct impacts of mechanization in a feedback loop diagram. In addition, the expected impacts of mechanization in the work relations are discussed. Finally, the current qualification initiatives of the sector are analyzed.

Chapter 8 proposes actions that could lead to the reconciliation of the supply and demand of labor in the Brazilian sugarcane agro-industry. Conclusions and recommendations were carefully shaped based on the key findings of the research work. The dissertation concludes proposing some topics that might be interesting for further research efforts in the short and medium term.

Chapter 2

2. Brazilian sugarcane agro-industry: Developments and trends

The objective of this chapter is to present specific features of the Brazilian sugarcane agro-industry focusing on its importance for energy generation. As background for understanding the state of the art of the sector, Sect. 2.1 briefly describes its key characteristics. Sect. 2.2 reviews the production of sugarcane-based ethanol including a broad view of its agricultural and industrial stages. Sect. 2.3 reviews the energy and the GHG emissions balance of Brazilian ethanol. The chapter concludes with general remarks about other general sustainability concerns associated with the production and use of sugarcane-based ethanol (Sect. 2.4).

2.1 Background

Sugarcane (*Saccharum officinarum*) is one of the most important commercial crops in the world. It is grown in over 100 countries and is an important source of labor in the rural areas of those countries (CGEE, 2009). According to IBGE (2012), more than 700 million tonnes of sugarcane were produced in Brazil using more than 9 million hectares in 2010 (Table 1). The area planted with sugarcane accounts for 2.2% of the total arable land in Brazil and about 30% of the world’s (Soetaert & Vandamme, 2009; Shikida, 2010).

Table 1: Production and harvested area of sugarcane. Brazil, 2009, 2010 and the projection for 2011

Variable	2009	2010	2011*
Amount produced (tonnes)	672,156,957	717,462,101	705,823,063
Harvested area (ha)	8,523,415	9,076,706	8,869,136

Source: IBGE, 2012
Note*: Projection

Brazil has five centuries of tradition in sugarcane production (Shikida, 2010) and is the world's largest producer and exporter of sugar (Brazilian-American Chamber of Commerce, 2011). The amount of sugar exported by Brazil during the harvest 2009/10 was more than 40% of the total world’s exports (Macedo, 2010). In addition, Brazil is the world’s second largest producer and exporter of ethanol fuel (RFA, 2011). The production of sugarcane in the country has increased considerably over the years (Fig. 4).

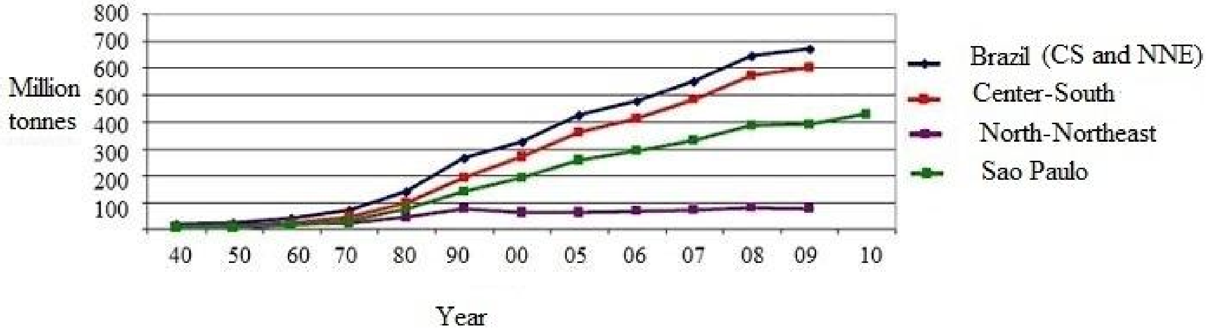

Fig. 4: Evolution of the sugarcane production. Brazil, by region, 1940-2010
Source: IBGE (1940-2009), IEA[2] (2010), apud Silva, 2011

The production of sugarcane is concentrated in the Center-West and Southeast regions of the country[1] (Fig. 5). The macro-region with the largest harvested area of the country is the Southeast (Table 2). In Brazil, sugarcane is the third most important culture in terms of area used after soy and corn (CGEE, 2009).

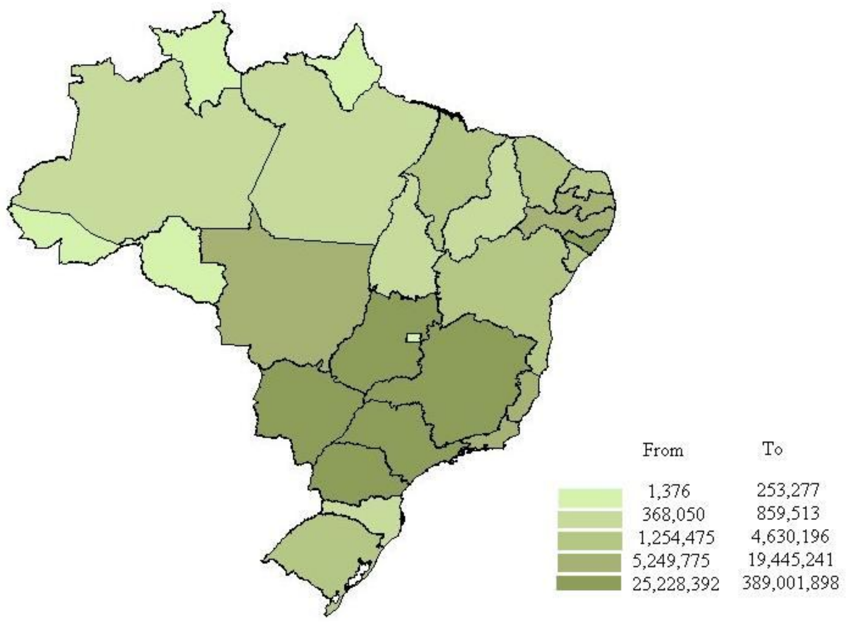

Fig. 5: Sugarcane production map (in tonnes). Brazil, by federal state, 2009
Source: IBGE, 2011

Sugarcane productivity is highly influenced by climatic variability and the specific characteristics of the producing areas. Examples include: the sugarcane variety, the composition and amount of fertilizer used, the physico-chemical characteristics of the soil, the management of pests and weeds, water availability, and techniques of planting and harvesting (BNDES/CGEE et al., 2008). Brazil has more than 500 commercial varieties of sugarcane, but the 20 main types hold 80% of the planted area (CGEE, 2009). In 2010, the Center-West region of the country produced 97.4 million tonnes of sugarcane while the Northeast produced

1 Brazil is divided into five macro-regions by IBGE: North, Northeast, Central-West, Southeast and South (Annex 1)

only 68.8 million tonnes even when both regions did not have not a significant difference in terms of area harvested (Table 2). This can be explained by the difference on average yields.

Table 2: Sugarcane harvested area. Brazil, by region, 2010

Region	Area harvested (in ha)
North	32,302
Northeast	1,233,739
Southeast	5,947,840
South	671,330
Center-West	1,191,495
Total	9,076,706

Source: IBGE, 2012

According to IBGE (2012), the average yield of Brazilian sugarcane was 79.4 tonnes/ha in 2010 and was expected to increase 0.3% in 2011 rising to 79.6 tonnes/ha being this figure equivalent to the best producing regions in other parts of the world (CGEE, 2009). The Center-West region had an average yield of 82 tonnes/ha in 2010 while the Northeast had only 56.4 tonnes/ha. The region with the highest average yield of Brazil is the Southeast with 83.4 tonnes/ha in 2010. From 1975 to 2000 there was an increase of 33% in the yield/ha of sugarcane in Sao Paulo state. During this period, the percentage of sucrose increased in 8% (Macedo, 2010).

Sao Paulo produces ca. 60% of the total country's ethanol. In 2009 in Sao Paulo 426 million tonnes of sugarcane were produced (ca. 60% of the national production) with 4.7 million hectares harvested (55% of the total area harvested) (IBGE, 2011). The Figure 6 shows the comparison of the total production and area harvested in Brazil and in Sao Paulo in 2009.

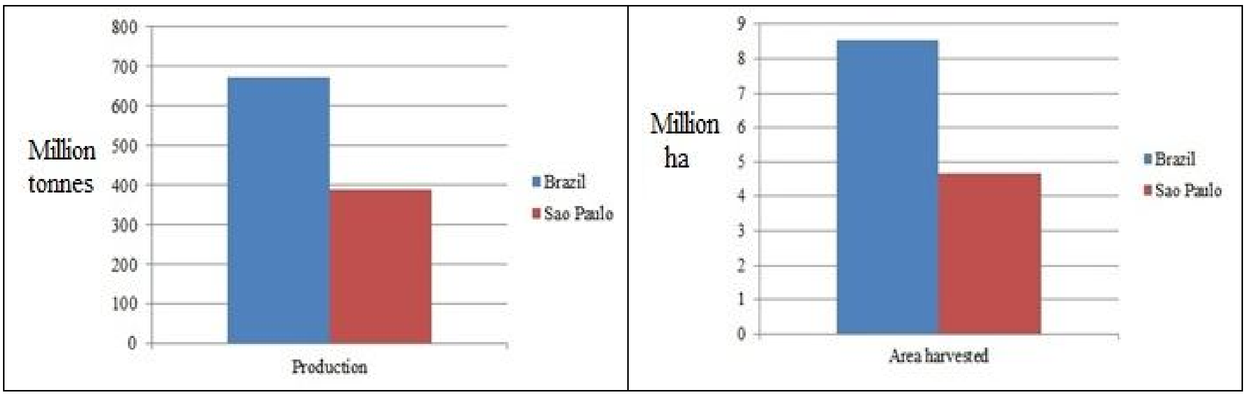

Fig. 6: Production of sugarcane and area harvested. Brazil and Sao Paulo, 2009
Source: IBGE, 2011

Sao Paulo state is located in the Southeastern region of Brazil. From its fifteen administrative regions[2] (*mesorregião geográfica*) Ribeirão Preto, São José do Rio Preto and Bauru are the ones with the highest production of sugarcane. These three regions together produced 212.2 million tonnes of sugarcane in 2009 accounting for 54.5% of the production of Sao Paulo and 31.6% of the total of Brazil (IBGE, 2011).

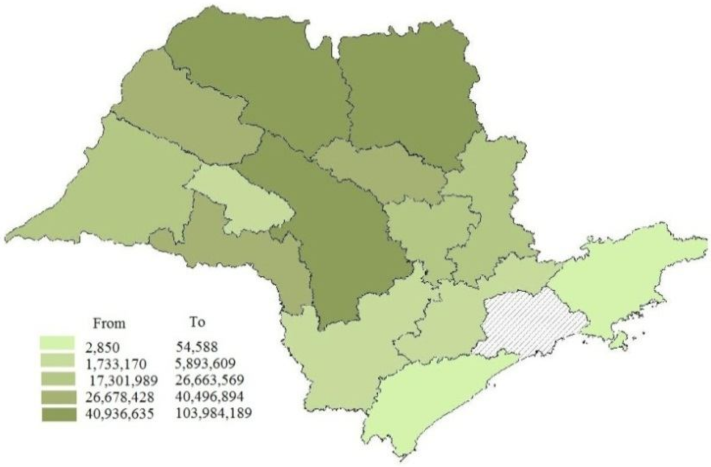

Fig. 7: Sugarcane production map (in tonnes). Sao Paulo, 2009
Source: IBGE, 2011

There were approximately 440 sugarcane mills in operation in 2010 from which 196 were located in Sao Paulo (UNICA, 2010). The distribution of the sugarcane processing mills as reported by BNDES/CGEE et al. in 2008 is shown in Figure 8.

Fig. 8: Distribution of the sugarcane processing mills in Brazil
Source: BNDES/CGEE et al., 2008

There are two major categories of distilleries for the production of ethanol from sugarcane: annexed and autonomous. An annexed distillery is the one that is constructed in conjunction

2 Sao Paulo state is divided into fifteen regions by IBGE: Ribeirão Preto, São José do Rio Preto, Bauru, Araçatuba, Araraquara, Piracicaba, Campinas, Presidente Prudente, Marília, Assis, Itapetininga, Macro Metropolitana paulista, Vale do Paraíba Paulista, Litoral Sul Paulista, Metropolitana de São Paulo.

with a sugarcane mill and an autonomous distillery is the one that has the aim of producing only ethanol. Most of the sugarcane producing units in Brazil are annexed. It is estimated that in Brazil there are less than 50 autonomous distilleries from the total number of units (Soetaert & Vandamme, 2009). The flexibility of using sugarcane to produce ethanol and sugar represents a significant technological adaptation of the Brazilian sugarcane agro-industry (BNDES/CGEE et al., 2008). The main products of the sugarcane processing in Brazil are sugar, hydrated and anhydrous ethanol. The major sub-products of the process are vinasse, a filter cake and bagasse. The production system will be analyzed with more detail in the following section.

2.2 Sugarcane-based ethanol

The basic technology used for the production of ethanol is the fermentation of sugar, or the hydrolysis and fermentation of starch. The production of ethanol is highly concentrated. In 2009, U.S.A. and Brazil together were responsible for the production of 88% of the world's ethanol fuel production while Brazilian ethanol alone accounted for 33% (F.O. Lichts, 2010). The main feedstock types used for ethanol production are corn (mainly in the U.S.A.), cereals and sugar beet (in Europe) and sugarcane (in Brazil) (F.O. Lichts, 2010). IEA reported in 2011 that the land-use efficiency of conventional ethanol from corn worldwide was 2,600 liters/ha while for sugarcane this figure was 4,900 liters/ha. According to CONAB (2008), the average yield of Brazilian sugarcane-based ethanol is 6,000 liters/ha. In U.S.A., the average yield of corn-based ethanol is ca. 4,200 liters/ha (RFA, 2008).

Sugarcane-based ethanol is produced through the fermentation of sugars extracted from the sugarcane (Fig. 9). The production process was described in detail by BNDES/CGEE et al., (2008). The initial stages of ethanol production are the same as for the production of sugar. After transported to the mill, the sugarcane is usually washed and the juice is extracted by roll-mills (sets ranging from four to seven successive three-roll mills). The saccharide juice is separated from the bagasse, which is used as fuel at the mill’s power plant. Some new facilities use diffusion to extract the juice, which is expected to have energy advantages. The juice is treated chemically for coagulation, flocculation and precipitation of impurities. The juice is then evaporated and crystallized to produce sugar or sent to fermentation reactors where yeasts are added for the production of ethanol. After fermentation the wine is sent to distillation columns where ethanol is recovered initially in hydrated form (ca. 6% of water in weight). Hydrated ethanol can be stored as a final product or dehydrated with the addition of cyclohexane. The anhydrous ethanol contains nearly 0.4% of water in weight.

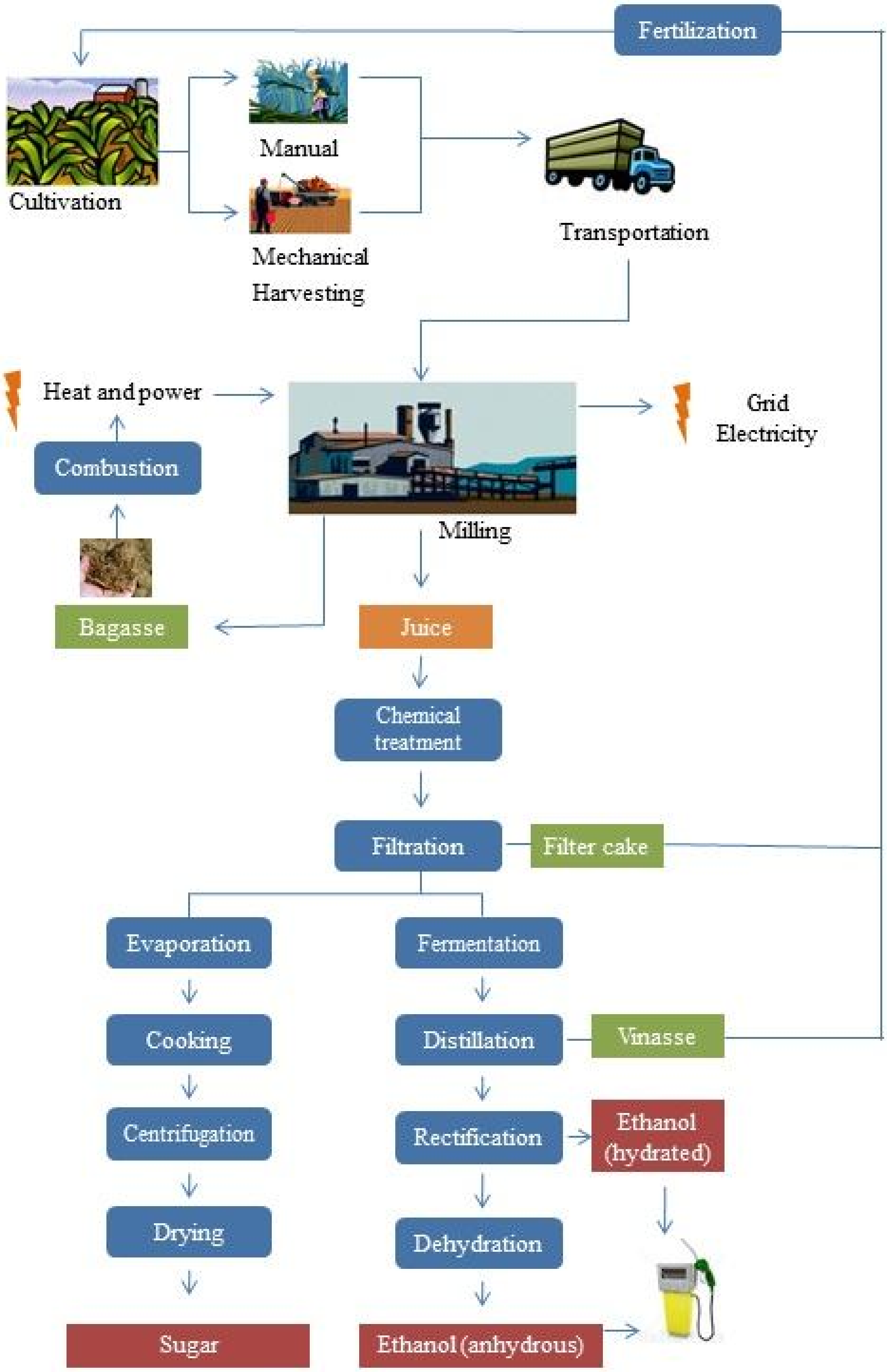

Fig. 9: Sugar and sugarcane-based ethanol production chart
Source: Missagia, 2011

All the energy consumed in the process can be supplied by a cogeneration system (combined heat and power production) installed in the mill using sugarcane bagasse as energy source (Fig. 10). One tonne of sugarcane produces approximately 280 kg of bagasse (50% water content) (CTC, 2011). The low calorific value of bagasse is ca. 7,500 kJ/kg (Macedo, 2002). Brazilian sugarcane mills are electrically self-sufficient and have exported increasing amounts of electric power surpluses to the public grids (REN21, 2011).

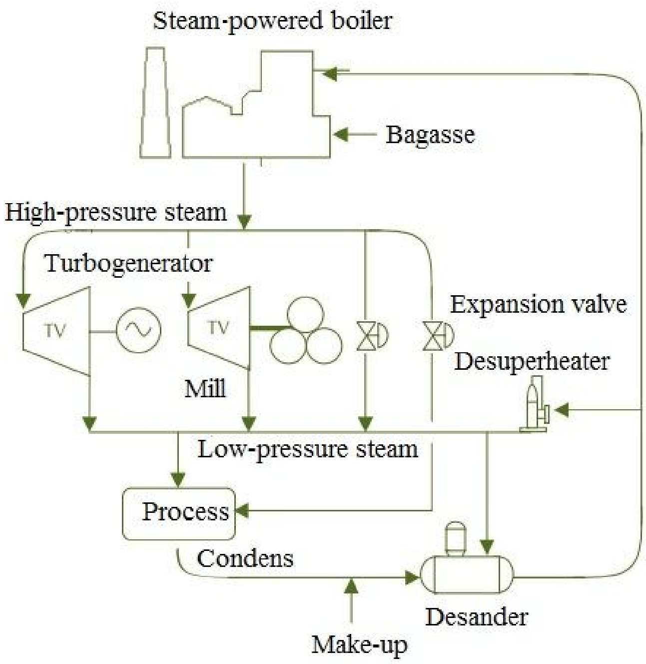

Fig. 10: Typical setup of a cogeneration system in the sugarcane agro-industry
Source: BNDES/CGEE et al., 2008

High pressure steam is produced by the heat released by combustion in boilers. The steam drives steam turbines for electric power production and mechanical drivers. The exhaust steam has low pressure and is able to meet the thermal energy requirements (BNDES/CGEE et al., 2008).

According to REN21 (2011), in Brazil during the 2009/10 sugar harvesting season, sugarcane bagasse generated 18.5 TWh of electricity, including 8.8 TWh of excess electricity that was exported into the grid. Electricity generation in Brazil, including public service power plants and self-producers was 509.2 TWh in 2010 (EPE, 2011). Therefore, bioelectricity from bagasse alone provided 3.6% of the total Brazilian electricity needs in 2010. This figure is expected to increase to 14% by 2020 (EPE, 2011). In 2010, the installed capacity of biomass cogeneration plants at sugar mills was 6.3 GW, representing 5.5% of the energy matrix of the country (EPE, 2011). IEA (2011) noted that in Brazil bioelectricity produced from bagasse represents around 15% of total income of the sugar mills. In addition, the production costs of electricity from bagasse are lower than those of producing electricity using other energy sources in Brazil (Fig. 11).

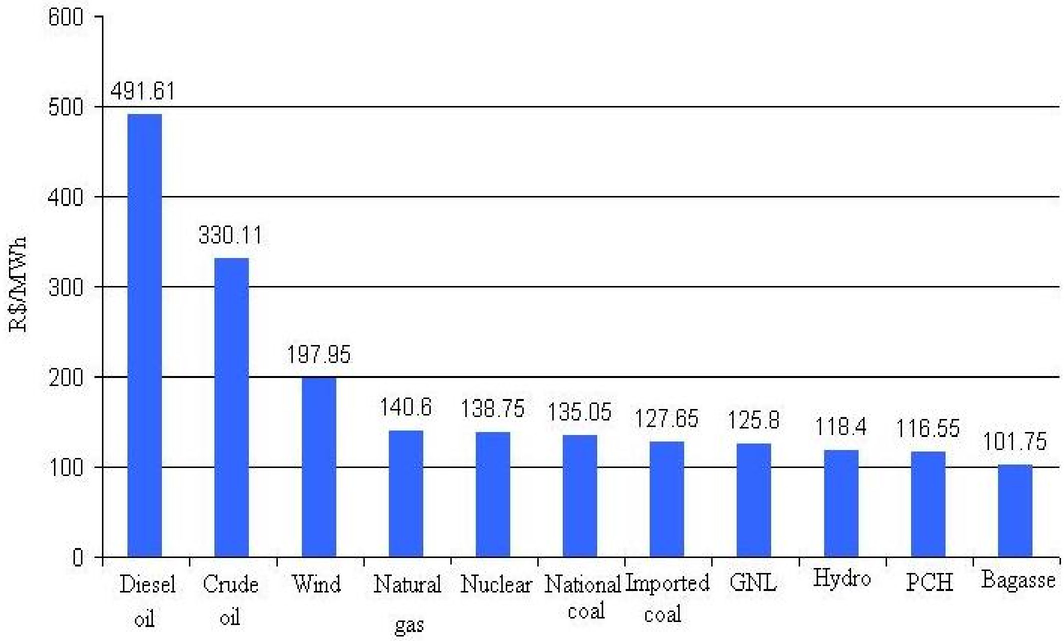

Fig. 11: Production costs of electricity in Brazil based on various raw materials
Source: ANEEL, 2008

Another advantage of the combustion of bagasse is its capability to cover the energy demand in the period of dry weather in the Southeast and Center-West regions where the biggest installed capacity of hydroelectric plants in the country is concentrated. Due to lower precipitation levels, shortages in hydropower often coincide with the sugarcane harvest season (from April until November) (Missagia, 2011).

Over the years, the sugarcane agro-industry was able to integrate its processes, obtaining benefits such as flexibility and reduced losses (Macedo, 2010). Technological advancements in the sector also enabled it to increase its productivity, improve its energy balance and reduce its emissions. These aspects will be covered within the next section.

2.3 Energy balance and GHG emissions

The main objective of the production of ethanol (and biofuels in general) is the replacement of fossil fuels derivatives, reducing the dependency on non-renewable sources whilst reducing the emissions of greenhouse gases (GHG) (Barros, 2010). In addition, biofuels could also support rural development through agricultural activities (UNEP, 2009).

Life cycle analyses (Fig. 12) are usually carried out to calculate energy consumption and emissions generated from feedstock production through to final use of the ethanol fuel. The pathway of ethanol will determine to what extent ethanol is capable of replacing fossil fuels since all the production technologies directly or indirectly involve the use of fossil resources (BNDES/CGEE et al., 2008).

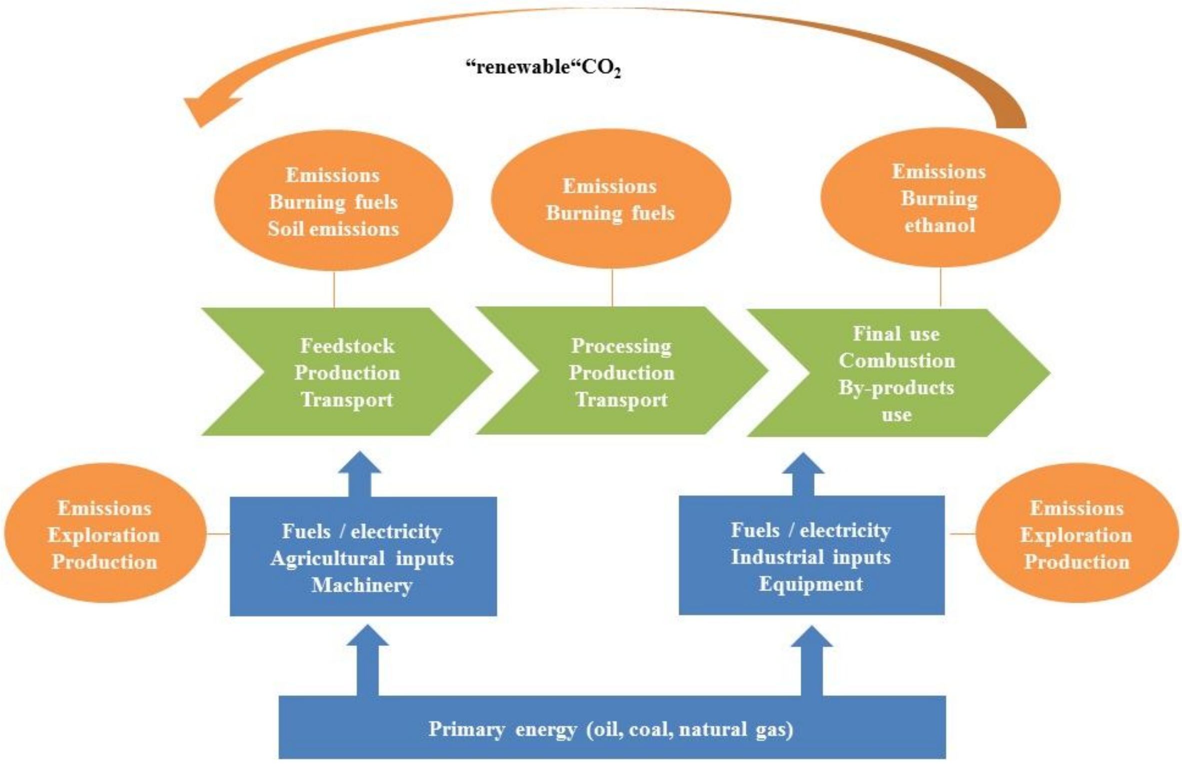

Fig. 12: Ethanol life cycle diagram
Source: BNDES/CGEE et al., 2008

Sugarcane production and processing are considered highly energy intensive activities requiring for each ton of Brazilian sugarcane 190 MJ in its agricultural stage (fossil fuels, fertilizers and others chemicals) and 1,970 MJ in its industrial stage (chemicals and bagasse) (Hassuani et al., 2005). Even before the end of the 1970s, studies were carried out to review the energy balance of Brazilian sugarcane ethanol fuel concluding that the ratio between the energy produced as ethanol and the total energy consumed during the production process was positive (Mousdale, 2008). According to Barros (2010), in Brazil, for each fossil energy unit used to produce sugarcane ethanol, 9.3 renewable energy units are produced. By 2020, the ratio between energy production and consumption is expected to increase to 11.6.

The calculation of the total direct emissions considers all the emissions directly associated with the production of the final output (e.g. biofuel or blend) and the emissions directly attributed to intermediate inputs (e.g. fertilizers) (Fig. 12). The agricultural phase accounts for most of the emissions in the full life cycle of ethanol (Galdos et al., 2010).

Diverse assumptions and methodologies lead to different results. There are also additional uncertainties due to the intrinsic unpredictability of the production of biofuels. An example of this are the emissions of N_2O (nitrous oxide) associated with the nitrification and denitrification processes of ammonium fertilizers used on the fields, since these emissions vary according to climate and soil type (Croezen et al., 2010). The distribution and use stages also vary broadly depending on the target market and the proportion of ethanol used in the fuel mix (Galdos et al., 2010).

There are also various methodologies used to calculate the mitigation potential of ethanol compared to its fossil fuel counterparts. Macedo (2010) for instance, calculated that Brazilian ethanol was able to mitigate 88% of the total emissions of gasoline along its life cycle under specific assumptions (Fig. 13).

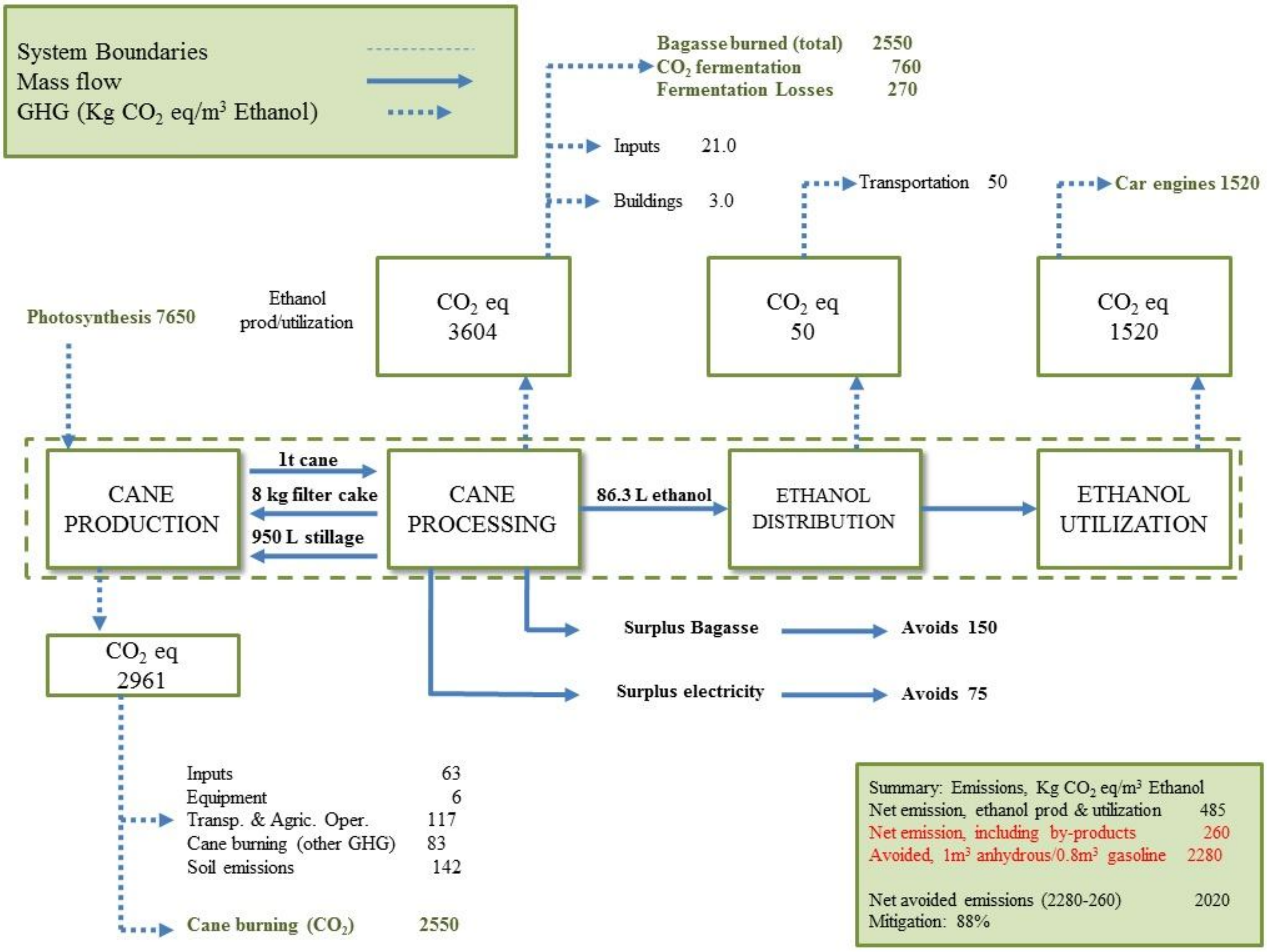

Fig. 13: Estimation of GHG emissions directly associated with the production of sugarcane ethanol
Source: Macedo, 2010

According to UNICA (2010), the use of sugarcane ethanol in Brazil resulted in a reduction of 600 million tonnes of CO_2 since 1975 due to its widespread consumption. While the use of biofuels for transport is still rather low in almost every country compared to petroleum (BP, 2010), the consumption of ethanol in Brazil accounts for 60-65% of the total fuel by volume for light gasoline fueled vehicles (which excludes natural gas and diesel) in 2009 (Macedo, 2010). The growth of ethanol consumption in Brazil is linked to the increased availability of flex fuel vehicles[3] (UNICA, 2010). Flex fuel vehicles were officially launched commercially

[3] The owners of flex fuel vehicles can choose the fuel (any proportion mixture of gasoline or hydrated alcohol) each tanking based on price, fuel availability, performance and consumption.

in the Brazilian market in 2003 (MDIC, 2012). Until December 2011 the share of flex fuel vehicles in the Brazilian market of light vehicles was 83.1% (Fig. 14) (MDIC, 2012). Since being launched, 15.3 million flex fuel vehicles have been sold, representing ca. 73% of the total sales from 2003 to 2011 while gasoline vehicles accounted for 22%, diesel vehicles for 0.5% and ethanol vehicles for 0.1% (MDIC, 2012).

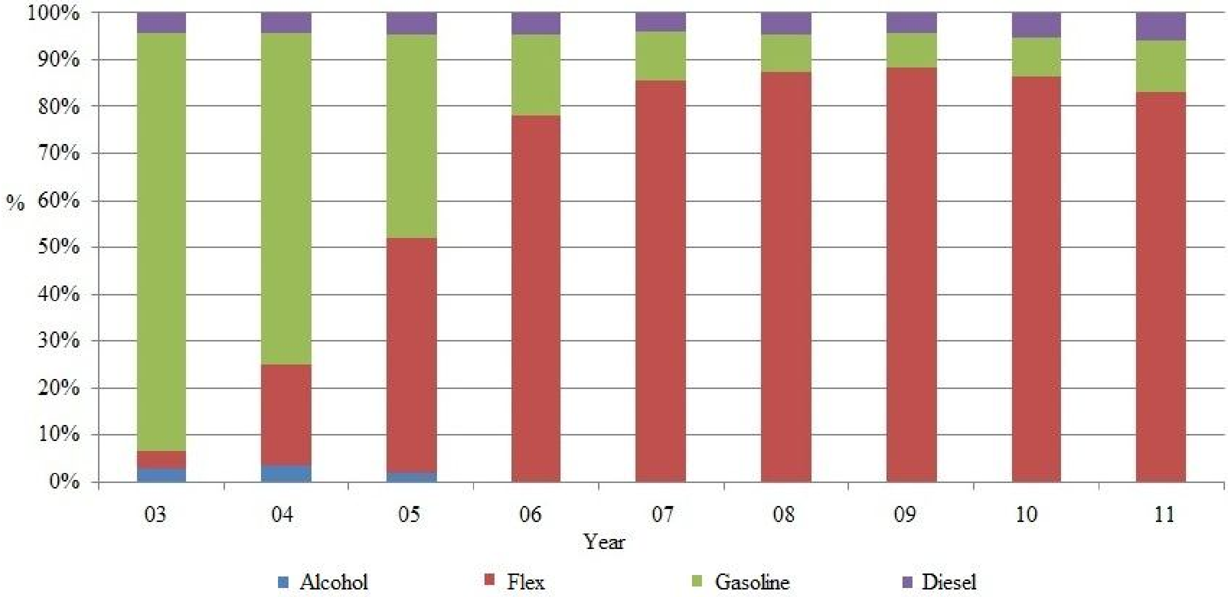

Fig. 14: Participation of the light traffic vehicles in the Brazilian sales per type of fuel
Source: MDIC, 2012

Currently flex-fuel vehicles in Brazil are available in 114 different models that are produced by ten manufacturers or imported from Korea. Furthermore, Brazilian manufacturers have developed flex-fuel motorcycles which first model was commercially launched in March 2009 (MDIC, 2012).

Even when accuracy has improved in the estimation of the direct life cycle emissions from biofuel production, the calculation of the indirect land use change (ILUC) emissions is still at an early stage. The trends of global agricultural markets indicate that new arable land will be required to meet future global demands for food and feed. Mobilization of new land to satisfy these requirements are likely to occur in spite of productivity increases in arable land currently used (Croezen et al., 2010). When marginal land enters production driven by the demand for biofuels, emissions could be generated due to the extensive effects from the conversion of non-agricultural land into farmland (Rajagopal et al., 2010). The concept of ILUC emissions includes the emissions associated with clearing vegetation and the cultivation of converted land. These emissions and the soil carbon content changes are difficult to predict, monitor, measure and control since there is no certainty that future developments will follow past trends. Estimates could be obtained using economic models and historical data on land use change (Croezen et al., 2010). There seems to be a consensus on the need to improve data and models, but regardless of the uncertainties, the US Environmental Protection Agency (EPA) recently considered Brazilian ethanol as an advanced biofuel since it reduces GHG compared to gasoline by 61% including ILUC emissions (EPA, 2010). According to UNICA (2011), the US EPA already acknowledged that the reductions of CO_2 from Brazilian ethanol compared to gasoline are up to 90% in some cases. The GHG emissions associated with the ethanol production are only a part of the concerns associated with the large scale production of this biofuel.

2.4 Sustainability concerns of the Brazilian sugarcane ethanol

Biofuels are a controversial topic. On the one hand, proponents bring up their potential advantages such as contributing to energy security and fostering rural development. On the other hand, opponents raise concern over sustainability and the possible negative impacts on food supply and ecosystems. The large scale production of biofuels involves a significant number of variables that could differ from one system to other even in the same country or region.

Measuring the sustainability of an energy system is a complex undertaking. Sustainability is a normative concept, containing values, perceptions and preferences that precede a scientific or technical analysis (CGEE, 2009). Depending on what argument is being supported or refuted, sustainability assessments could be based on subjective assessment and incomplete information. Furthermore, some aspects of ethanol production such as environmental impacts should receive greater attention in future evaluations. For instance, a sustainability study carried out by Smeets et al. (2008) assessed possible bottlenecks in the production of sugarcane ethanol in Sao Paulo. After analyzing seventeen areas of concern the research work concluded that there are both: (i) a lack of region-specific and current data of some of the areas of concern, and (ii) the need for more accurate methodologies, indicators and criteria to estimate (especially) indirect effects of ethanol production.

The aforementioned study also concluded that biofuel production in Brazil is not expected to have a significant impact on food and feed markets. This argument has been supported by other studies (Hoffmann, 2006; Hernandez, 2008). Furthermore, a recent study from the Food and Agriculture Organization of the United Nations (FAO) found that Brazil is among the four only countries in Latin America that could expand biofuel production without affecting food security (with Argentina, Paraguay and Colombia) (Bloomerang, 2012).

Regarding the economic dimension of sugarcane ethanol produced in Brazil it has been widely agreed that it does not represent a concern since this country is probably the lowest-cost producer in the world (Demirbas, 2011). In a number of countries, biofuels receive subsidies or tax exemptions from the government in order to maintain economic competitiveness against traditional transportation fuels (van den Wall Bake et al., 2009). Brazilian ethanol competes with gasoline without subsidies. An accurate economic balance depends very much on the assumed price for crude oil (Luo et al., 2009). According to EMBRAPA (2009), Brazilian ethanol is competitive when the oil price is higher than 38 US$/barrel. Production costs in Brazil have recently been recorded at less than half the costs in Europe (Demirbas, 2011) where according to EMBRAPA (2009), the production cost of a barrel of wheat ethanol is 154 US$ (Fig. 15).

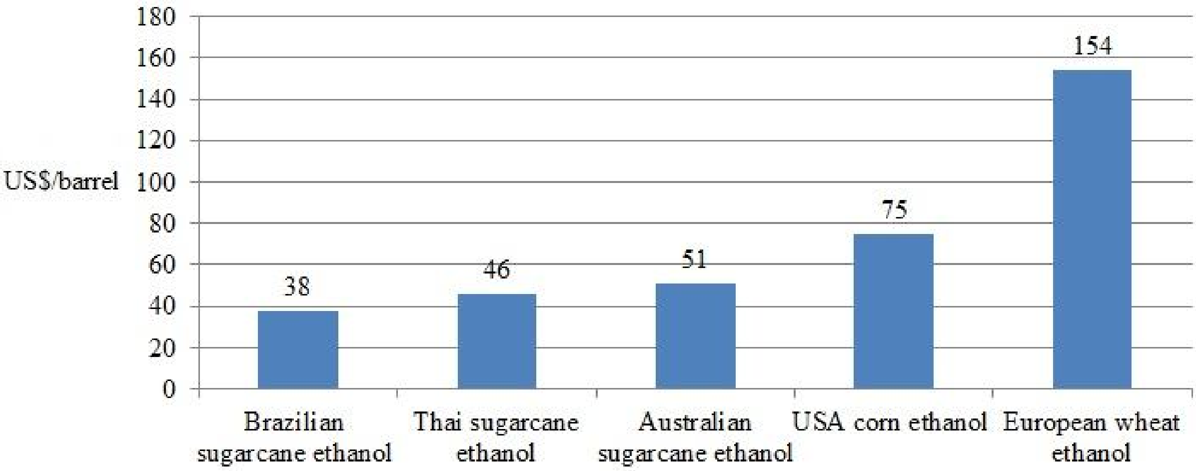

Fig. 15: Cost of ethanol production in various countries
Source: EMBRAPA, 2009

A wide range of literature notes that production costs of Brazilian ethanol have decreased continuously over the last three decades. According to van den Wall Bake et al. (2009), all the sub-processes associated with the sugarcane production chain contributed to cost reductions, being the most important contributor the increasing yields. The industrial costs have been reduced primarily due to increasing scales of the ethanol production plants. These costs are expected to decrease in the next years based on the experience curves observed (van den Wall Bake et al., 2009).

Public and private Brazilian research institutes are carrying out studies on a wide number of areas along the entire production chain. Some examples include: the development of new conversion technologies (e.g. ethanol from cellulose), technologies for economical use of by-products and residues, sugarcane genetic modification, agricultural mechanization, biological pest control, recycling of water, etc.

Technological advancements led to a cost-effective production of Brazilian ethanol, making Brazil an attractive option for countries looking to import biofuels. The European Union is an especially attractive market for Brazil given the EU Directive on Renewable Energy of 2009 which endorsed a binding target of 20% share of renewables in energy consumption by 2020 (EC, 2009) (Sect. 6.1).

New laws have been launched in 2010 in USA and the EU imposing domestic requirements for sustainable production of ethanol. Even when these developments are generally positive, they could create challenges for the development of an international ethanol market (de Souza et al., 2011). The plans of increasing the exports of Brazilian ethanol to new markets, making it a global trade commodity, have raised further awareness of its environmental and social sustainability. Regarding to the sustainability criterion defined by the European Union, for instance, Brazilian producers probably will not have great difficulties as they have already make advancements on matters such as labor practices, burn-off of sugarcane fields and the use of water and vinasse (de Souza et al., 2011).

Negative environmental impacts such as water consumption, contamination of soils and water shields due to the use of fertilizers and chemicals, and loss of biodiversity take place during the production of sugarcane even when they are less significant compared to other crops (Walter et al., 2008). Monitoring environmental aspects is essential for a sustainable development of the sector.

Since ethanol production conditions vary widely, attention has been drawn to possible production sustainability certification schemes. Certification systems could be an approach to develop and standardize sustainability criteria identifying differences of comparable products.

According to Lehtonen (2011), even when sustainability is regularly conceptualized as a combination of three ‘pillars’ (economic, social and environmental), in practice most of the research work and political attention is focused on the environmental pillar while the social dimension has remained the least developed of the three. On the one hand, certification schemes could provide opportunities to break the entrenched power structures of the Brazilian biofuel scene when providing openings for the entry of new players, if such schemes were designed carefully to avoid tendencies towards further concentration of resources (Lehtonen, 2011). On the other hand, certification systems have raised concerns regarding the possibility of small players to comply with the requirements stipulated and to pay for the certification process (UNEP, 2008). One of the proposals for tackling this challenge is to enable small producer group certification schemes. According to UNEP (2008), group certification can be a mechanism to include more smallholders in these markets, assuring that biofuel certification does not leave them out. Another option would be the implementation of a social certification similar to the one of the National Biodiesel Production Program (PNPB). The biodiesel Social Fuel Stamp is a mechanism that encourages the purchase of products from small farmers. In order to obtain the stamp the biodiesel producers must purchase minimum raw material percentages from family farmers, set contracts with farmers and provide technical assistance and training. Biodiesel producers with the Social Fuel Stamp receive benefits such as tax incentives, better credit terms, and classification as a socially friendly company (MDA, 2011; Barros, 2010). Nevertheless, these kinds of programs do not guarantee real social benefits for the producers. According to UNRISD (2011), the biodiesel Social Fuel Stamp program encountered challenges such as little organizational capacity of poor smallholders, which resulted in failures such as low yields, bankrupted companies and abandoned smallholders.

Some aspects that deserve further attention are: nitrogen pollution, degradation of soils and aquatic systems (Martinelli & Solange, 2008); levels of water consumption, impacts on water quality and conservation (Silva, 2008); loss of biodiversity, land use change considering direct and indirect impacts; impacts of fertilizers and agro-chemical use (Walter et al., 2008); and genetically modified organisms (Smeets et al., 2008). Other concerns recurrently referred to in the literature are the negative environmental impacts of the sugarcane burning practice and the work conditions of the manual sugarcane harvesters (Martinelli & Solange, 2008). These topics are closely related to the mechanization of the sugarcane harvest and will be covered in the following chapters.

Chapter 3

3. Contextual exploration

The objective of this chapter is to analyze the economic, social, environmental and agronomic implications of the mechanization of the sugarcane harvesting and the complexity of their interactions. Sect. 3.1 provides a brief review of key historical developments in Brazil since the introduction of sugarcane. Sect. 3.2 gives an introduction to the agro-industry's labor market. Sect. 3.3 is focused on giving an overview of the sugarcane harvesting operation and its significance within the sugarcane production process. The chapter concludes with a model showing cause and effect relationships among the impacts of the mechanization of the sugarcane harvest (Sect. 3.4).

3.1 Historical developments

Sugarcane has been cultivated in Brazil since 1532 when it was introduced in Pernambuco (Northeast) and became one of the first products exported by the Portuguese settlers to Europe (UNICA, 2008). During the first half of the 17^{th} century, Brazil was a large producer and exporter of raw sugar. Nevertheless, some aspects such as the competition caused by the production of sugarcane in other colonies and the late adoption of technologies after the industrial revolution hindered the importance of Brazil as sugarcane producer and exporter. Even after losing production capacity, the Brazilian mills provided for the period 1500-1822 income equivalent to nearly twice of that obtained from gold and nearly 5 times more than that obtained from all the other agricultural products such as coffee, cotton and wood (Cardoso, 2010). The sector's growth recovery began after the First World War, when damaged European mills reduced European sugar production. This led to an increase in the sugar price and the establishment of new plants in Brazil, mainly in Sao Paulo.

For 30 years (from 1975 to 2005) Brazil was the world's largest producer of ethanol fuel. Its use as an automotive fuel began in 1975 and since then production has increased more than 28 times (Soetaert & Vandamme, 2009).

The systematic use of ethanol from sugarcane for fuel purposes was divided into five periods by Barros (2010) as shown in the Fig. 16 below:

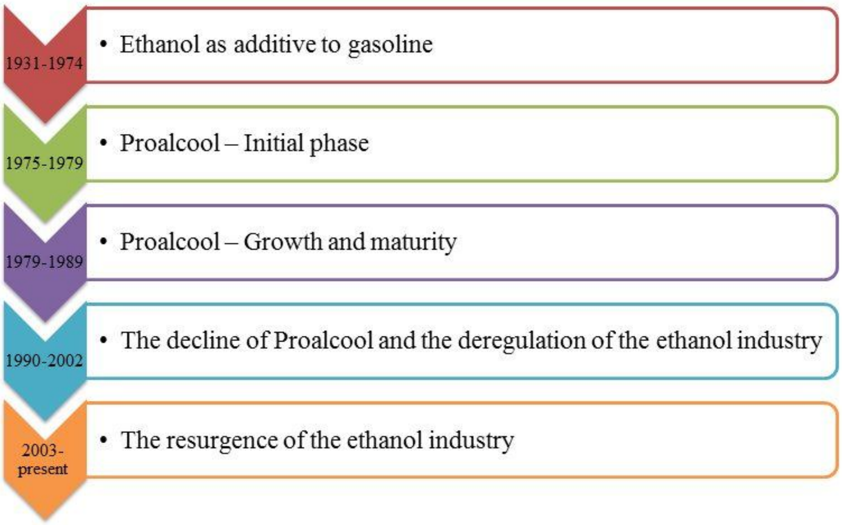

Fig. 16: Historical timeline of Brazilian ethanol
Source: Barros, 2010

A. Ethanol as gasoline additive (1931-1974)

In 1931 the Brazilian Government implemented a compulsory gasoline blend of at least 5% anhydrous ethanol. At first, the mandate applied only to imported gasoline, but was then applied to the domestically produced gasoline (BNDES/CGEE et al., 2008). During this phase, the endorsement of the ethanol industry was more associated with the variations in the sugar market than to the requirements to replace energy imports (Barros, 2010).

B. Proalcool – Initial phase (1975-1979)

The Brazilian Government fostered ethanol fuel in order to respond to the 1973 oil crisis. Its strategy was to launch The National Alcohol Program (*Proalcool - Programa Nacional do Álcool*) in 1975 on a nation-wide scale. The objective of the program was to reduce dependence on oil imports by promoting the production of anhydrous ethanol as gasoline additive. By that time, the oil exports of Brazil accounted for four fifths of its consumption. The *Proalcool* program leveraged the existing and underutilized industrial capacity of the sugar sector, mostly by constructing ethanol distilleries annexed to sugar plants. By 1980, Brazil surpassed the 3 billion liter production per year and the ethanol content of gasoline was approximately 17% (Barros, 2010).

C. Proalcool – Growth and Maturity (1979-1989)

The second phase of the *Proalcool* program started in the early 1980s, driven by the second oil crisis. New goals set for the program included the expansion of sugarcane plantations and the production of hydrated ethanol (E100) as a stand-alone fuel substitute (Barros, 2010). The

Brazilian car industry implemented the technical changes necessary for vehicles to safely operate on the new fuel. The investment required for this phase of the program was funded through soft loans by the government (IEA, 2004). In 1984, ethanol powered cars represented over 94% of total automobile production. In 1989/90, ethanol production augmented to 12 billion liters and the ethanol fuel consumption accounted for ca. 50% of total light vehicle fuel consumption in volume terms (Barros, 2010).

D. The decline of Proalcool and the Deregulation of the Ethanol Industry (1990-2002)

The ethanol production in Brazil became unattractive with the reduction of oil prices in 1986 and the recovery of sugar prices in the international market. In 1989, most of the incentives given to the ethanol industry during the previous 15 years were eliminated (Barros, 2010). Furthermore, the mechanisms to create safety reserves failed and consumers faced sporadic supply shortages of ethanol. Emergency measures became necessary, such as reducing the level of ethanol in gasoline, importing ethanol and using gasoline-methanol mixes as a substitute for ethanol (BNDES/CGEE et al., 2008). In 1990, the pure ethanol vehicles production dropped to 10.9% because of a loss in the confidence on the reliability of ethanol supply (Briquet, 2007). Winfield (2008) noted that in addition to these setbacks, distress emerged concerning labor problems, water contamination, air pollution from the burning of cane residues and the Food vs. Fuel debate. During the late 1990s the share of sales of ethanol powered vehicles dropped to nearly zero (Barros, 2010).

E. The resurgence of the Ethanol Industry (2003-present)

In 2003 flex-fuel cars were launched in the Brazilian market. Flex-fuel cars have the option of using gasoline (with 20-25% anhydrous ethanol), hydrated ethanol, or both depending on price, performance or availability conditions (BNDES/CGEE et al., 2008). Also in 2003 a federal law established a mandatory blend of a maximum of 25% ethanol and 75% gasoline (E25) and a minimum of 20% ethanol and 80% gasoline (E20) by volume of anhydrous ethanol in the entire country (Briquet, 2007). The consumption of hydrated ethanol in the domestic market started to grow again. Ever since, the Brazilian sugarcane industry has expanded at high rates (BNDES/CGEE et al., 2008). Even when currently market forces drive the demand growth for ethanol, government policies have a major influence on market dynamics. Policy support for its consumption includes tax incentives and the ethanol-use mandate (Barros, 2010).

The aforementioned events influenced the production levels of sugar and ethanol (Fig. 17). The capability of sugarcane juice to be diverted towards sugar or ethanol enables their production to be adapted depending on specific market demands. The percentage of sugarcane used for ethanol in 1975 was 14% while it was 61% in 2008 (Macedo 2010).

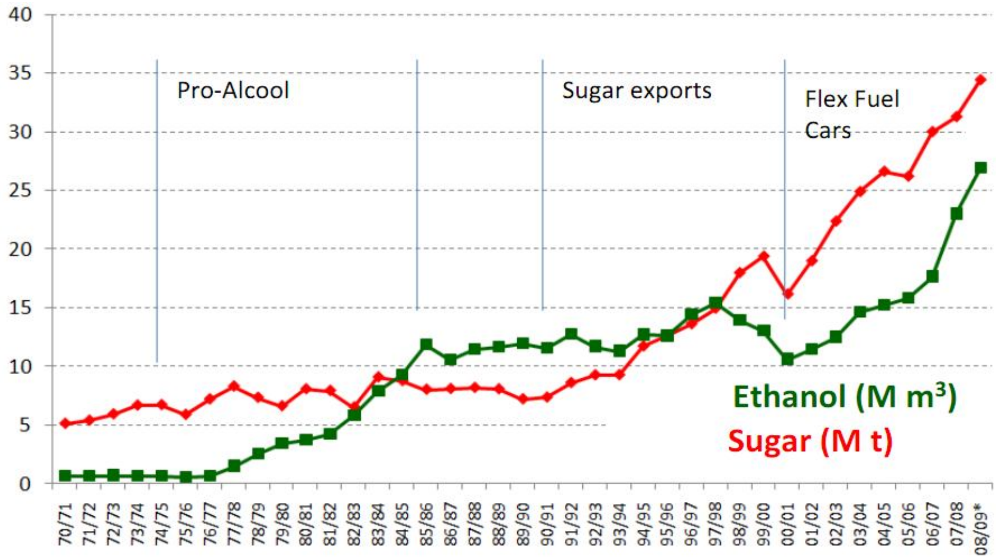

Fig. 17: Evolution of the sugar and ethanol production. Brazil, 1970-2008
Source: Macedo, 2010

The Brazilian sugarcane agro-industry generated annual gross earnings equivalent to US$ 23 billion in the harvest 08/09 (UNICA, 2010). For comparison, in 2009 the Brazilian GDP was estimated at US$ 2.4 trillion (Global Finance, 2010). In addition, sugarcane products accounted for 17.7% of the total Brazilian energy supply matrix in 2010 (Fig. 18).

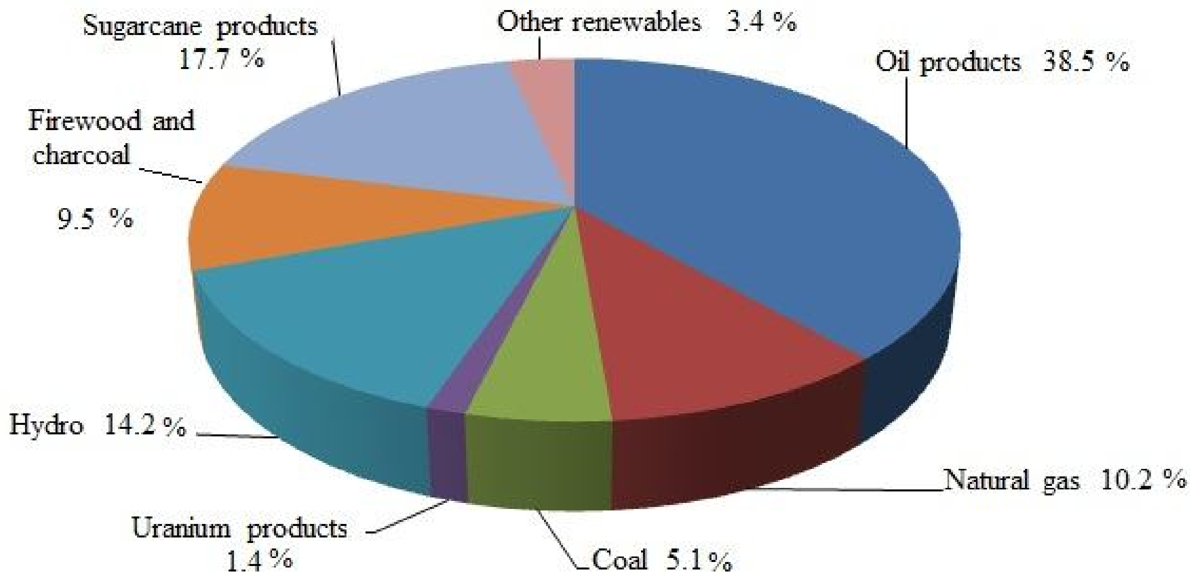

Fig. 18: Brazilian energy supply matrix, 2010
Source: EPE, 2011

Biomass (including firewood, sugarcane bagasse, black liquor and other wastes) accounted for 4.7% of the total Brazilian domestic electricity supply in 2010 (EPE, 2011) (Fig. 19).

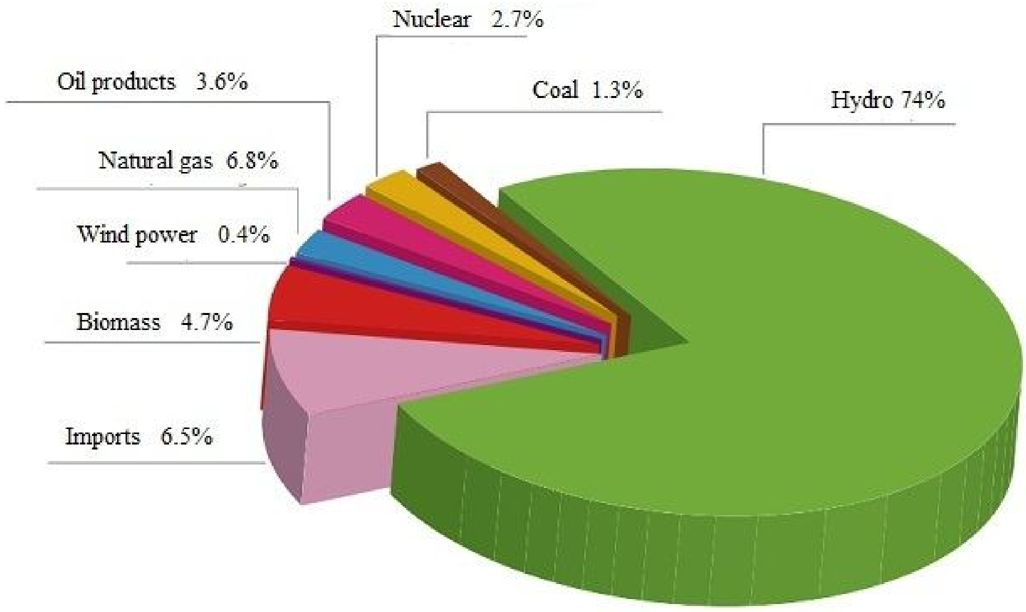

Fig. 19: Brazilian electricity supply matrix, 2010
Source: EPE, 2011

The importance of the sugarcane agro-industry for local economies is analyzed in the following section.

3.2 Labor in the sugarcane agro-industry

Rural economies continue to be of great importance in Brazil despite the intense industrialization fostered by the public policies of the mid-1940s of the last century and the accelerated rural-urban migration linked to this process (Parra, 2009). In Brazil, the agro-industrial complexes in general (rural industry and trade, livestock and agriculture) accounted for 26.5% of the total GDP in 2008 (CEPEA, 2009). The term agro-industry is defined as the sum of agricultural activities including all the operations for the production and distribution of agricultural supplies. It involves the suppliers of goods and services, agricultural producers, processors, transformers, and distributors involved in the generation and flow of agricultural products until it reaches the final consumer (Silva, 2008). The number of direct workers[4] in the Brazilian sugarcane agro-industry is a figure that varies slightly in the literature depending on the source, mainly depending of the definition used. It is estimated that the sector employs approximately one million workers (Shikida, 2010; UNICA, 2011). In 2008, ca. 629 thousand

4 A worker is defined as a person that works for an employer (legal entity or natural person), fulfilling work shifts and receiving a wage, products or benefits (housing, food, clothing, etc.). These workers are part of the labor market of wage earning employees. The employees could be either permanent or temporary (IBGE, 2011).

workers were hired for the production of sugarcane in Brazil (PNAD, apud Moraes et al., 2011). The regional distribution of the sector is illustrated in Fig. 20.

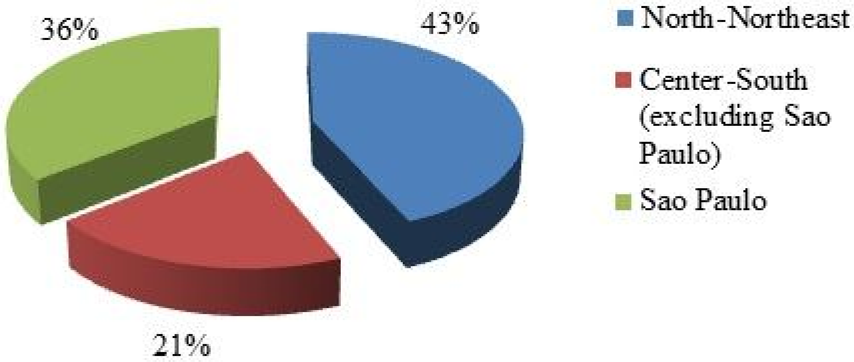

Fig. 20: Distribution of sugarcane salaried workers. Brazil, by region, 2008
Source: Adapted from data from PNAD, apud Moraes et al., 2011

The processing and production of sugar and ethanol has upstream and downstream linkages with other sectors. A model of input-output matrixes[5] reveal that the whole national economy tends to grow as the ethanol production expands (BNDES/CGEE et al., 2008).

In relation to the indirect[6] and induced[7] employment effects of the sugarcane agro-industry, some of the highest are assumed to be on other farming activities, the chemical sector (including fertilizer), oil refining, commerce, logistics and real estate (BNDES/CGEE et al., 2008). According to Scaramucci & Cunha (2008), the processing of one million tonnes of sugarcane for ethanol production generates ca. 5,700 jobs in the sectors of: sugarcane, farming, sugar, ethanol, electricity, mineral extraction, steelwork mining and metallurgy, machines, vehicles and parts, oil and gas, chemical, food, civil construction, transformation and trade and services. Some examples of these effects are shown in Table 3.

5 Input – Output analysis is a quantitative economic technique which was developed to show the interdependencies between the various branches of a specific economy (Raa, 2011).

6 Indirect employment is generated in the industries that produce intermediate deliveries to the sugarcane and ethanol production sectors (Smeets et al., 2008)

7 Induced employment is generated or lost due to the effects of sugarcane and ethanol production (e.g. the change in employment in case sugarcane production replaces food production and the employment generated as a result of the increase in income spending) (Smeets et al., 2008).

Table 3: Direct, indirect and induced effects of processing one million tonne of sugarcane for ethanol production in selected sectors

Sector	Production value (million R$)	Employment
Sugarcane	44.5	1,467
Ethanol	97.8	211
Sugar	8	31
Farming (other)	14.3	697
Trade and services	81.3	2,679
Chemical sector	13.9	41
Oil and gas	29.5	12
Machines, vehicles and parts	9.3	51
Food	15.4	93
Transformation: other	16.8	287

Source: Adapted from Scaramucci & Cunha, 2008

BNDES/CGEE et al. (2008) estimated that in 2005 ca. 4.1 million working people were dependent on the sugarcane agro-industry. This estimate was based on an input-output matrix study of the Brazilian economy published in 2001 which estimated that there were 1.43 indirect jobs and 2.75 induced jobs for each direct employee in this sector. If these relationships were still maintained, more than 5 million persons would have been dependent on the sugarcane agro-industry including the direct, indirect and induced jobs in 2011, being broadly distributed through the Brazilian territory and including a wide range of activities.

As sugarcane production expands, its indirect and induced effects are also expected to increase. Cunha & Scaramucci (2006) carried out a study based on an extended input-output model with mixed technologies (considering manually and mechanically harvested sugarcane and ethanol produced in annexed and autonomous distilleries). This model aimed to quantify the socioeconomic impacts of the expansion of ethanol production in Brazil so as to replace 5% of the estimated global demand for gasoline in 2025. The resulting direct, indirect and induced effects indicate that if ethanol production were augmented by ca. 800% more than 5 million of jobs would be created. It was also pointed out that the Brazilian GDP would increase by 11.4% (Cunha & Scaramucci, 2006).

3.2.1 Job characteristics of the sector

The sugarcane agro-industry includes two major different production processes: agricultural (sugarcane production) and industrial (raw and refined sugar and ethanol production). The jobs associated with it are distributed along these supply chains. The evolution of the number of jobs per activity is shown in Fig. 21.

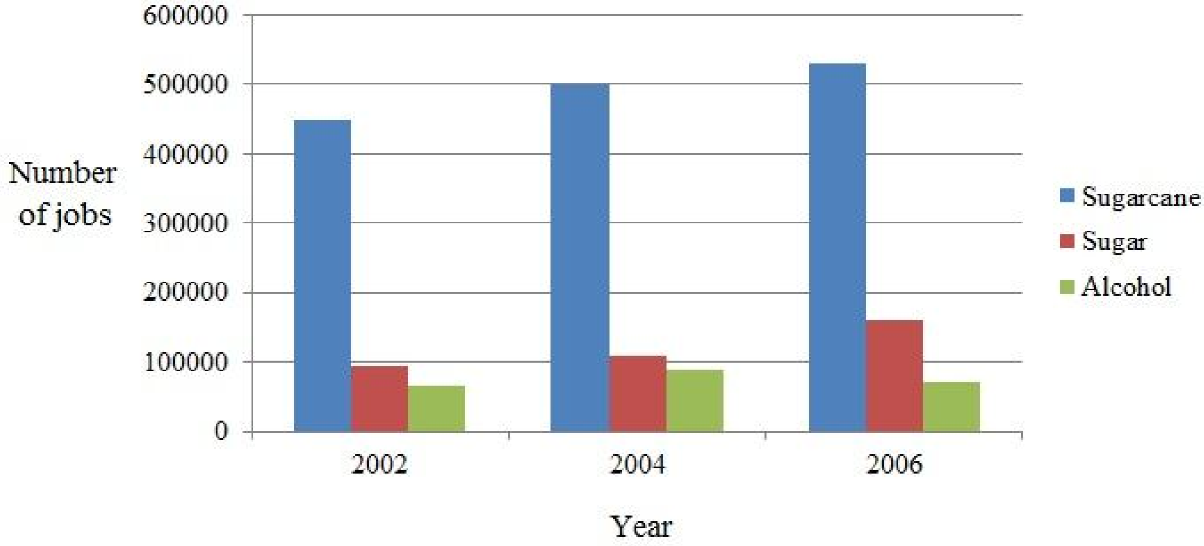

Fig. 21: Evolution of the number of jobs in the Brazilian sugarcane agro-industry by activity 2002, 2004 and 2006
Source: Adapted from data from PNAD, 2002, 2004 and 2006, apud Hoffman & Oliveira, 2008

Ethanol production can also be considered a labor intensive sector in relation to other energy related activities. A source from 2008 reported that the production of ethanol per unit of energy required 38 times more human labor than coal, 50 times more than hydroelectricity and 152 times more than oil (BNDES/CGEE et al., 2008). In addition, the production of biomass is an activity that involves low investment costs per job generated compared to other industrial sectors such as metallurgy, automotive, chemical, intermediary, etc. (Goldemberg et al., 2008).

In relation to the industrial jobs, there is a range of positions associated with the processing of sugarcane. These jobs are carried out in sugarcane mills including: boiler operators, inspectors, laboratory analysts, etc. (Parra, 2009).

Agricultural jobs include occupations from the soil preparation to the final destination of the harvested crop, the sugar mill (Table 4).

Table 4: Examples of jobs associated with the production of sugarcane

Culture treatment and soil preparation	Vinasse applier
	Manual herbicide applier
	Herbicide truck driver
	Herbicide tractor driver
	Cultivation supervisor
	Cultivation machine operators
Planting	Bus driver (workers transportation)
	Tractor driver (furrow digging)
	Material distributor
	Chopping responsible
	Planting supervisor
	Quality assessment

Others	Farming supervisor
	Topographer
	Administration auxiliary
	Maintenance mechanics
	General services

Source: Carrara, 2009

Sugarcane is a semi-perennial culture. The cultivation of sugarcane in Brazil is based on a "ratoon system", meaning that after the first cut is carried out, the same plant is cut every year before being replaced. Its production cycle is on average five to six years of cuts (Fig. 22) (CGEE, 2009).

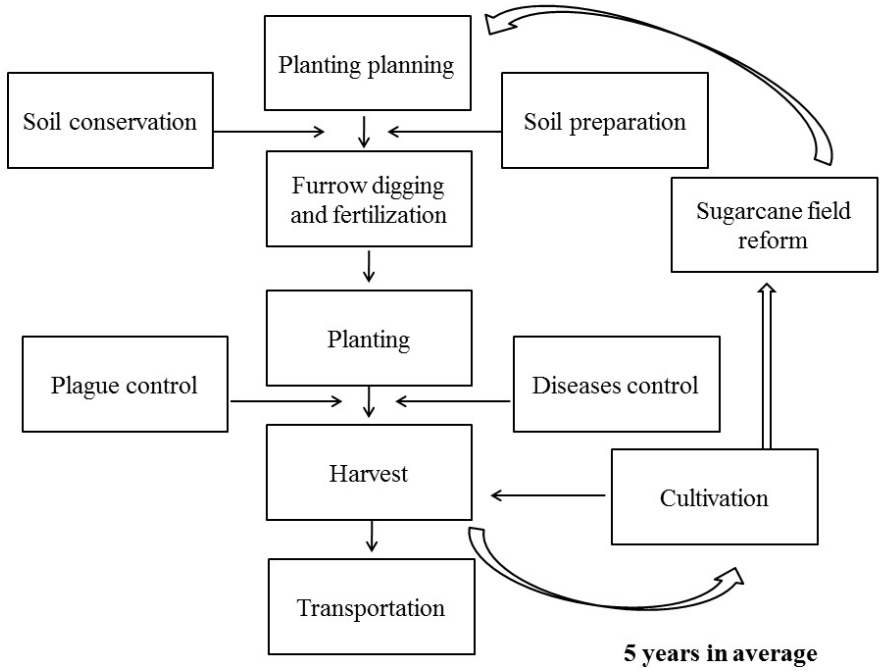

Fig. 22: Simplified diagram of the production of sugarcane
Source: Donzelli, 2009, apud Cardoso, 2010

The workforce demand of the sugarcane agro-industry varies during the year because of the seasonal operation of the plants which depends on the productive cycle of the sugarcane (BNDES/CGEE et al., 2008). This cycle affects all the occupational categories, agricultural and non-agricultural alike (Fredo, 2011). In regional terms, Brazil has two harvesting seasons: from April to November in the Center-South and from September to March in the North-Northeast (CGEE, 2009). The harvest season is characterized by a large number of hires, especially for the agricultural activities (Fig. 23). The highest demand for temporary workers in the sugarcane agro-industry is linked to the activities of sugarcane plating, pest control and harvesting (BNDES/CGEE et al., 2008).

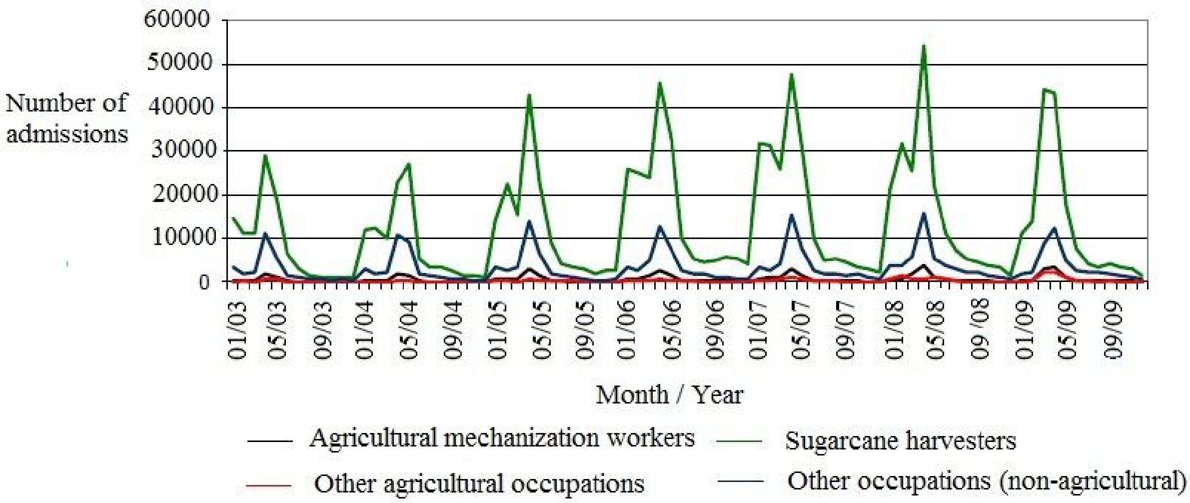

Fig. 23: Admissions of the sugarcane agro-industry by categories. Sao Paulo, 2003-2009
Source: Fredo, 2011

Over the years, the employment seasonality had decreased as a consequence of extended harvests (BNDES/CGEE et al., 2008).

3.3 Sugarcane harvesting operation

Depending on whether the sugarcane harvest is carried out manually or mechanically, the configuration of the work distribution varies widely along the production stages (Table 5). When done manually, harvesting concentrates a significant part (83%) of the days/worker demanded. On the other hand, when the harvesting operation is carried out mechanically, the distribution among the production stages is more even (Gonçalves, 1999).

Table 5: Percentage of days/worker used for the sugarcane production under manual and mechanical operations. Sao Paulo, 1995/96

Operation	Manual	Mechanical
Soil preparation	0.9	22.2
Planting and fertilizing	7.7	28.3
Cultural treatments	8.4	32.3
Harvest	83	17.2

Source: Gonçalves, 1999

Besides its importance in saving time and reducing the amount of workers required, the sugarcane harvesting operation also has noteworthy economic and environmental implications for the agro-industry in general and the sustainability of ethanol in particular.

For biofuels as a whole, the raw material of ethanol accounts for the major share of the total costs. Sugarcane represents ca. 67% of the total costs of ethanol (Soetaert & Vandamme, 2009). In Brazil, the contribution of the feedstock in the cost structure of total hydrated ethanol costs has remained relatively stable within the last three decades (van den Wall et al., 2009). Harvesting is responsible for a significant fraction (ca. 30-50%) of the costs associated with the sugarcane production (Moraes, 2007; Graziano, 2011). As reference, harvesting costs represent up to 20% for manioc and less than 10% for soy, wheat and corn (Graziano, 2011).

In relation to the environmental implications of the sugarcane harvesting operation, the burning of sugarcane straw is a topic often discussed in the literature. The burning of sugarcane is a widespread practice in most of its producer countries. The burning of sugarcane before harvest represents 11% of the harvested residues burned annually in the world (Galdos et al., 2009).

In order to carry out a permitted sugarcane field burning it is necessary to have previous authorization and it is limited by several factors (wind direction, hour of the day, etc.). The procedures for application and prior communication are defined in the Law No. 11241/02. During the last years, the environmental legislation became more stringent regarding the authorization and licensing of the harvest with previous burning (MMA, 2011).

This practice keeps organic matter and nutrients from returning to the soil. There is an overall trend for a decrease in soil organic matter content under conventional sugarcane cropping techniques in the long term (Galdos et al., 2009). The combination of low soil cover and erosive precipitation can lead to soil losses by surface runoff (Galdos et al. 2010). Burning has been maintained because manual harvest is not economically feasible without it (Galdos et al., 2009; Moraes, 2007). If the sugarcane was not previously burned, the sugarcane harvesting cost would double (Moraes, 2007). The mechanization of the sugarcane harvesting operation with currently available technologies enables an economically feasible harvest without the need for pre-burning.

3.3.1 Mechanization of the sugarcane harvesting operation

The sugarcane agro-industry shows significant economies of scale. This scheme fosters the adoption of technologies aimed at greater productivity and reducing the fixed costs (BNDES/CGEE et al., 2008). The mechanization of cultivation started in the 1970s during the establishment of the *Proalcool* program. During this decade, mechanization efforts combated the lack of workers during the sugarcane harvest operation (Alves, 2009). The planting process is also being mechanized. However, this equipment can compact the soil in an inconvenient way, reducing the life of the sugarcane field and its productivity (Nastari, 2010). Currently in Sao Paulo the load, transportation, and cultivation of sugarcane is fully mechanized (Moraes, 2007).

The mechanization of the sugarcane harvest was implemented already in the 1980s (Cardoso, 2010). It received more investment in the 1990s with the deregulation of the industry (Plec et al., 2007). One sugarcane harvester machine is able to reap an average of 500 to 700 tonnes a day, replacing up to 100 workers (Nastari, 2010).

There are other machines supporting the mechanical harvesting operation. A fleet usually comprises four or five harvesting machines. Each machine is associated with two sets of trans-shipment that could be operated by tractors or trucks. Therefore, each harvest fleet needs 12 operators (Nastari, 2010).

For each fleet there should also be:

- One workshop truck (*caminhão-oficina*): Responsible for repairing all fleet machinery. The truck is driven by a qualified driver and two helpers (the maintenance team is usually comprised of a mechanical and a welder).
- Convoy truck (*caminhão-comboio*): Responsible for refueling and lubricating all fleet machines. It requires a driver and an operator.
- Water tank truck (*caminhão-pipa*): This kind of truck is always present when working with raw sugarcane, as straw increases the risk of fire.
- Furrow tractor (*trator de esteira*): Responsible for towing mechanical harvesters when they get stuck.
- Field-plant vehicle (*veículo de ligação campo–usina*): Responsible for supplying spare parts and tires.

Each fleet requires approximately 18 specialized workers per shift**.** Three shifts would employ approximately 54 qualified operators per fleet per day (Nastari, 2010). This estimate varies in the literature. Alves (2009) calculated that around 66 direct workers would be required to operate one fleet. Table 6 below shows a specific case study taken from Carrara (2009). According to these figures, the workforce ratio for a specific mill when comparing mechanical harvesting with manual harvesting is 1:6 when considering 24 hours of operation.

Table 6: Comparison of the number of employees for the mechanical and manual sugarcane harvesting operation

In order to harvest 3,200 tonnes of sugarcane (in 24 hours)	
Mechanical harvesting	Manual harvesting
	400 sugarcane manual harvesters
12 harvester operators (4 harvesting machines / 24 hours)	10 bus drivers
24 trans-shipment operators	30 operators of loaders and trailers (5 loaders and 5 trailers)
9 *folguistas* (persons that replace workers having days off – and therefore without a specific work schedule)	6 *folguistas*
3 mechanics	0.75 mechanics
2 lubricators	0.5 lubricator
1 convoy driver	0.5 convoy driver
3 firefighter driver	0.75 firefighter driver
9 chopper	12 chopper
12 drivers to transport sugarcane	18 drivers to transport sugarcane
Total: 75 workers	Total: 479 workers

Source: Carrara, 2009

Currently, there are two trends in the sugarcane sector (Table 7). On one hand, there are mills that are replacing their manual sugarcane harvesters for harvesting machines gradually (in traditional producing regions). On the other hand, according to a personal interview with the industrial manager of a sugarcane mill, there are productive units that are being implemented (in the areas where the culture is being expanded) that were planned to be fully mechanized from their establishment.

Table 7: Comparison of the two mechanization trends in Brazil

Comparison criteria	Usina São João (gradual mechanization)	Usina São Francisco (planned to be mechanized from its establishment)
Location	Araras (Sao Paulo)	Quirinopolis (Goias)
Production	3 million tonnes/harvest	5 million tonnes/harvest
Area	6,000 ha	Planned to be 22,000 ha
Terrain characteristics	Suitable for partial mechanization	Suitable for total mechanization
Percentage of mechanization	80% of the self-produced sugarcane 60% of the total*	80% of the total (currently) Planned to be fully mechanized (100%)**
Profile of harvester's operators	Mostly ex-manual sugarcane harvesters	Local inhabitants of the city. High percentage of women.

Source: Research data

*Note: Currently, 5% of the sugarcane produced by external producers is harvested mechanically. The maximum amount of sugarcane that will be possibly harvested mechanically by external producers is estimated in 50%. Regarding the self-produced sugarcane, ca. 20% is unlikely to be mechanized due to the terrain characteristics.

** Note: The Sao Francisco mill is still considered in a phase of consolidation.

In order to better understand the differences among these two schemes, two working units of the group *SJC Bioenergia* were studied. The first (*usina São João)* is located in Araras (in Sao Paulo: this mill has started out mechanization 20 years ago). The second one (*usina São Francisco)* is located in Quirinopolis (in Goias – Brazilian Center-West) and started operations in 2006.

There are also disadvantages to mechanization. According to Olicana (2008), mechanization can cause less uniform re-growth of the ratoons and losses compared to manually harvesting. According to FAPESP (2011), the loss during mechanical harvesting in sugar plantations today is around 10%. The loss of sugarcane depends on the soil preparation, systematization, furrow symmetry, and the preparation and calibration of the machines (Carrara, 2009). In addition, the percentage of mineral and organic impurities in the sugarcane could increase with mechanical harvesting but these are directly linked to the soil preparation practices. An increase in these levels would require modifications of the industrial processes since it could cause mechanical waste (Carrara, 2009). The technology currently available also causes soil compaction, which encourages erosion and makes it difficult for water to penetrate the soil (Olicana, 2008).

To conclude, it can be noted that the mechanization of the sugarcane harvesting operation has a number of challenges and opportunities. The next section will study their interactions.

3.4 Implications of the mechanization of the sugarcane harvest in Brazil

In order to provide a systematic analysis of the impacts of mechanization of the sugarcane harvest, agronomic, economic, environmental, and social implications were categorized as follows:

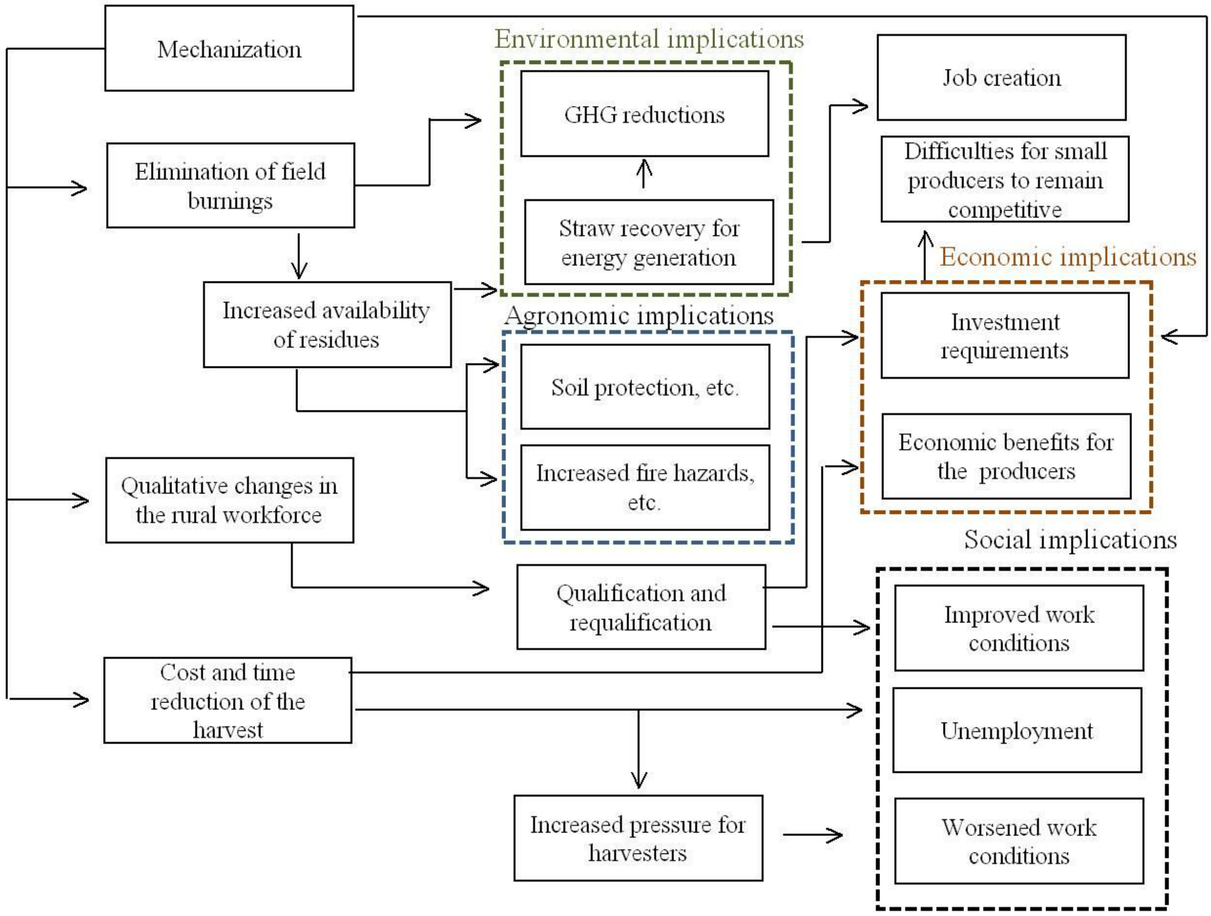

Fig. 24: Economic, social, environmental and agronomic implications of the mechanization of the sugarcane harvest
Source: Research data

- *Elimination of the need for sugarcane fields burning*

It is expected that 80% of the sugarcane harvested in the main producing regions of Brazil will be harvested without burning by 2014 (Galdos et al., 2009). When the sugarcane is harvested mechanically (without previous burn) or manually (after burning) the carbon balance of the agricultural phase differs. In the literature, there is a wide variety of studies which compare sets of variables for their carbon balance calculations. The Table 8 shows results of a study from 2010 which compared the emissions of the burned and raw sugarcane harvesting system for specific cases in Brazil.

Table 8: Carbon inputs and outputs of sugarcane production in Brazil under burned and raw harvesting systems

Carbon inputs and outputs/ Carbon equivalent	**Burned***	**Raw***
Inputs		
Labor	20.2	6.1
Machinery	26.7	27.8
Diesel	21.4	56.6
Nitrogen	61.7	61.7
Phosphorous	1	1
Potassium	9.9	9.9
Lime	9.6	9.6
Seeds	5.1	5.1
Herbicides	29.1	29.1
Insecticides	1.8	1.8
Vinasse disposal	13.2	13.2
Transport of consumables	5.6	5.6
Cane transport	41.5	41.5
CH_4 and N_2O from burning	196	0
Back carbon from burning	1535.5	0
Litter decomposition	11.6	70.4
Nitrogen fertilizer	110.7	110.7
Liming	47.7	47.7
Vinasse	41.9	41.9
Filter cake	18.9	18.9
Total inputs	2209.2	558.5
Outputs		
Soil carbon		1500
Biochar	30.7	
Total outputs	30.7	1500

Source: Adapted from Galdos et al., 2010

Note*: In kg $C_{eq}.ha^{-1}.yr^{-1}$

Under the mechanized scenario (raw harvesting system), there is an expected increase in the carbon inputs associated with diesel fuel. The difference among the diesel fuel consumption with manual (burned sugarcane) and mechanical harvest (raw sugarcane) in the whole production chain was estimated at ca. 39% under specific conditions (Carrara, 2009). The carbon inputs associated with diesel fuel represent a 6.3% of the total carbon input associated with this method (Galdos et al., 2010).

In this study, it was concluded that the CO_2, together the CH_4, N_2O and black carbon from burning, represents 78.4% of the total carbon inputs associated with the sugarcane harvesting system with previous field burning. Black carbon comes from the incomplete combustion of biomass. As a component of aerosol, black carbon has a scattering and an absorption effect on the atmosphere. The input carbon associated with the litter decomposition is higher in the harvest system without previous burning. This is because of the acknowledgment of the N_2O emissions from litter decomposition. As litter decomposes, part of the carbon is emitted as

CO_2 into the atmosphere, and the rest is incorporated into the soil, increasing the carbon stocks. However, the dynamics of soil carbon stocks are influenced by several aspects such as previous carbon stocks, soil texture, degree of soil disturbance, etc. The reference study concluded that ca. 75% of the carbon inputs associated with the production of sugarcane could be saved if the burning practice were eliminated (Galdos et al., 2010).

- *Increased availability of sugarcane residues*

As the sugarcane harvest is mechanized and the in-field burning practice is eliminated, the sugarcane can be harvested raw, leaving behind its residues (straw or trash). According to Hassuani et al. (2005), the amount of residues generated from the sugarcane cultivation depends on various factors such as the topping height, cane variety, age of crop (stage of cut), climate, soil, etc. It is estimated that on average, the amount of sugarcane straw is 140 kg/tonne of sugarcane in a dry basis (d.b.) or 250 kg/tonne of sugarcane with 50% moisture (EPE, 2008; CTC, 2005). According to CTC (2007), it is estimated that each hectare of sugarcane could generate up to 11.5 tonnes of straw (d.b.).

Hassuani et al. (2005) noted that of the total energy obtainable from the sugarcane plant, sugars account for only one third. The other two thirds are found in the plant fiber (composed of cellulose, hemicellulose and lignin) which form the bagasse and the tops and leaves (sugarcane straw by-products). According to Herrera (2005), the vegetative structure of sugarcane is: 50% stalks, 10% tops, 25% leaves, and 15% roots. Cortez & Leal (2010) noted that the sugarcane straw composition varies, but on average is made up of ca. 24% of lignin, 39% of cellulose and 30% of hemicellulose.

Sugarcane straw firing efficient boiler technologies has much potential for electricity and heat generation (UNICA, 2007). The quality of the biomass combustion process depends on both the fuel properties and the type of the combustion application used (van Loo & Koppejan, 2008).

One of the key efficiency factors in biomass combustion is its moisture content. High moisture content has negative effects on the combustion process. For a moist fuel, the heating value decreases because a portion of the combustion heat is used up to evaporate the moisture in the biomass (van Loo & Koppejan, 2008). The lower heating value (LHV) of sugarcane trash, evaluated under specific conditions, is estimated at ca. 12 MJ/kg (Macedo, 2002). The average moisture content of bagasse has been estimated at 50%. For dry leaves this value has been estimated at 13.5% (ranging from less than 10% to almost 30%), for green leaves 67.7% (ranging from 60% to 80%), and for sugarcane tops 82.3% (Table 9) (CTC, 2012; Hassuani et al., 2005). It is important to note that these values were observed when the straw was recovered from the field. The straw available at the sugarcane mill usually comes with average moisture of about 15% (Walter, pers. comm., 2012). CTC (2012) noted that sugarcane straw collected in the field, and evaluated under specific conditions, shows an average higher heating value (HHV) of 17 MJ/kg (d.b.) while the estimated heating value of bagasse is 18 MJ/kg (d.b.).

The volatile matter content influences the thermal behavior of solid biofuels. The volatile matter of sugarcane bagasse is ca. 81% of its weight. For dry leaves this figure has been estimated to average 84%, for green leaves 80% and for the sugarcane tops 79% (d.b.) (Hassuani et al., 2005). For comparison reasons, Lusatian lignite has an average of 50% volatile matter (d.b.), meaning that is a less reactive fuel compared to sugarcane bagasse/straw (van Loo & Koppejan, 2008).

Fuel composition is another important factor for the biomass combustion as it influences its calorific value, emissions and could create ash related problems like slagging (van Loo & Koppejan, 2008). The composition of the sugarcane straw depends on the weather conditions, soil characteristics, etc., making generalization impossible (CTC, 2012).

Carbon, hydrogen and oxygen are the main components of solid biofuels. Carbon and hydrogen are oxidized during combustion by exothermic reactions forming CO_2 and H_2O. The content of carbon and hydrogen contributes positively to the HHV while the content of oxygen affects it negatively (Obernberger et al. 2006). When comparing the carbon content of sugarcane bagasse and its straw by-products, it is possible to notice that there are no large differences. As mentioned before, their differences in HHV can be explained by their difference in moisture content levels.

During combustion the nitrogen is almost entirely converted to gaseous N_2 and nitric oxides NOx. The amount of nitrous oxide (N_2O) is very low in modern solid biofuel furnaces (Obernberger et al. 2006).

The ash content is the mass of inorganic residue remaining after combustion of a fuel under specific conditions (Obernberger et al. 2006). CTC (2012) carried out an evaluation of plants that burn up sugarcane straw in boilers. This report noted that there were large variations in the amount of ash generated. These levels varied from 3.1% to 47.5% with an average of 15% and a moisture content of 27.3%. This variation is very high. This could be at least partially explained by the high variation in straw composition caused by variables such as weather conditions, soil characteristics, etc. Hassuani et al. reported in 2005 that from a specific sample analyzed, the ash weight content (d.b.) was 3.9% for dry leaves, 3.7% for green leaves, 4.3% for tops and 3.6% for bagasse. Rossell (2005) estimated that the average ash content of the sugarcane straw as a whole is 8%.

The ash content informs the choice of the appropriate combustion technology and influences the logistics concerning ash storage and ash utilization/disposal (Obernberger et al. 2006). Ash composition (chlorine (Cl) and sulfur (S) contents) of biomass fuels are the main factors having an impact on the risk of bed agglomeration in fluidized bed boilers, and on the rate of boiler fouling, deposit formation, slagging, and super heater corrosion (Hiltunen et al., 2008).

During combustion the chlorine contained in the biofuel mainly forms gaseous HCl, Cl_2 or alkali chlorides such as KCl and NaCl. Some impacts of Cl are the corrosive effect of chloride salts and HCl on metal parts in the furnace and boiler and HCl and particulate (KCl, NaCl, $ZnCl_2$, $PbCl_2$) emissions. According to Obernberger et al. (2006), PCDD/F (chlorine dioxins) can be formed in very small amounts from all solid biofuels containing chlorine. PCDD/F emission related problems are to be expected for fuels with chlorine concentrations above 0.3 w-% (d.b.). In addition, chlorine induced corrosion and HCl emissions problems are to be expected at fuel concentrations above 0.1 w-% (d.b.). Green leaves and tops exceed the aforementioned guiding values (with 0.4 w-% (d.b.) and 0.7 w-% (d.b.) respectively). Measures against corrosion include automatic heat exchanger cleaning systems and the coating of boiler tubes. The PCDD/F-emissions can be significantly decreased by reducing the entrainment of unburned fuel particles, by ensuring a complete combustion of the flue gas and a complete burnout of the fly ash particles (Obernberger et al. 2006).

The sulfur contained in the solid biofuels forms mainly gaseous SO_2 and alkali and alkaline earth sulphates. The residual sulfur remains in the flue gas as aerosols and in a gaseous form as SO_2 (in minor quantities as SO_3). The efficiency of sulfur fixation in the ash depends on the concentration of alkali and alkaline earth metals (especially calcium) in the fuel. The importance of sulfur is not primarily in SO_2 emissions (which are usually not significant due to typically low concentrations) but in its role in corrosion processes. Emissions-related problems are to be expected at sulfur concentrations above 0.2 w-% (d.b.). The guiding concentration value for problems with corrosion caused by sulfur is 0.1 w-% (d.b.). The green and the dry leaves showed this exact value in the results of the analysis. The strategies for reducing SOx emissions and corrosion are the same as those for chlorine emissions. In addition, other elements that play a major role in corrosion mechanisms are K and Na.

The presence of the major ash forming elements Al, Ca, Fe, K, Mg, P, Si and Ti affect the ash melting behavior and corrosion (Obernberger et al. 2006). The sugarcane by-products vary widely on this front. For instance, the content of K_2O was reported to be as low as 1.7 g/kg for sugarcane bagasse and as high as 29.5 g/kg for the sugarcane tops (d.b.) (Cortez & Leal, 2010).

Table 9: Characterization of sugarcane bagasse and straw by-products

Characterization	Green leaves	Dry leaves	Tops	Bagasse
Proximate analysis	% weight*			
Moisture content	67.7	13.5	82.7	50
Ashes	3.7	3.9	4.3	3.6
Fixed carbon	15.7	11.6	16.4	14.9
Volatile matter	80.6	84.5	79.3	81.5

Note:* Dry basis
Source: Hassuani et al., 2005

Table 10: Ultimate analysis of sugarcane bagasse and straw by-products

Characterization	Green leaves	Dry leaves	Tops	Bagasse
Ultimate Analysis	% weight*			
Carbon	45.7	46.2	43.9	46.4
Hydrogen	6.2	6.2	6.1	6
Nitrogen	1	0.5	0.8	0.1
Oxygen	42.8	43	44	43.8
Sulphur	0.1	0.1	0.01	0.04
Chlorine	0.4	0.1	0.7	0.04

Note:* Dry basis
Source: Hassuani et al., 2005

Table 11: Ash analysis of sugarcane bagasse and straw by-products

Characterization	Green leaves	Dry leaves	Tops	Bagasse
Ash Analysis	content (g/kg)			
P_2O_5	0.5	2	2.5	0.5
K_2O	2.7	13.3	29.5	1.7
CaO	4.7	3.9	2.6	0.7
MgO	2.1	2.2	2.5	0.5
Fe_2O_3	0.9	0.5	0.2	2.3
Al_2O_3	3.5	1.4	0.5	2.3
	content (mg/kg)			
CuO	<0.6	<0.6	<0.6	-
ZnO	9	15	35	-
MnO_2	169	120	155	62
Na_2O	123	128	119	45

Note:* Dry basis
Source: Hassuani et al., 2005

Combustion technologies are commercially available around the world and play a major role in the generation of energy from biomass (van Loo & Koppejan, 2008). Technologies include fixed bed (grate) combustion systems and fluidized bed combustion systems.

In grate combustion applications the fuel is kept on the grate within the combustion chamber for the time necessary to complete combustion (van Loo & Koppejan, 2008). There are various types of grate firing alternatives including fixed, moving, rotating and travelling grates.

There are various kinds of fluidized bed furnaces including Bubbling Fluidized Bed (BFB) and Circulating Fluidized Bed (CFB). In BFB the fuel is dropped down a chute from above into the combustion chamber where a bed, usually of silica sand, sits on a nozzle distributor which supplies air into the chamber with a speed of 1-2.5 m/s. The bed normally has a temperature from 800 to 900^{o}C (USG, 2007). Complete combustion occurs without the need of re-injection with CFB, the air velocity is higher (5-10 m/s) and the unburned particles in the flue gas are collected in a cyclone, and reinjected into the fluidizing bed (van Loo & Koppejan, 2008).

From Table 9 above, it is possible to note that the moisture levels of sugarcane by-products are high (over 50% for green leaves, tops and bagasse). While both fluidized bed combustion systems and grate technologies are appropriate for highly moist fuels, the BFBs furnaces cope more easily with the varying particle sizes and moisture contents. Grate technologies operate better with more stable fuels with constant characteristics. Given the large variations reported for sugarcane straw characteristics, the fluidized bed combustion could be more attractive for this specific biomass. In addition to these advantages fluidized bed combustion systems usually have lower emissions compared to grate firing.

Nevertheless, one disadvantage with fluidized bed combustion systems is that they are usually more expensive. BFBs are a practical option only with larger plants with a nominal boiler capacity greater than 10 MW_{th}. CFBs deliver very stable combustion conditions but it is relatively costly. The use of CFB technology demands small fuel size and involves difficulties when running the facility at partial load. The use of CFBs is justifiable for plants with boiler capacities over 30 MW_{th} (USG, 2007). In order to select the appropriate power technology for sugarcane straw, the advantages and disadvantages of each technology should be considered. In order to develop large scale facilities using sugarcane trash as fuel in Brazil, it will be necessary to tackle the technical challenges in short-term.

UNICA (2007) forecasted that by the 2020/21 harvest the generation of bioelectricity from sugarcane (using 75% of the bagasse and 50% of the straw available) could account for 14,400 MW, which would represent 15% of the Brazilian electricity matrix predicted for that year.

Besides energy gains, the emissions otherwise produced by the use of fossil fuels in thermal power plants would be avoided.

Other uses for sugarcane rests are also being studied such as gasification and hydrolysis to convert cellulose, pre-treatment techniques, and compression of biomass such as pelletizing, briquetting, balling and torrefaction. The use of advanced technologies is aimed at the production of liquid fuels, fertilizers and solid fuels with an increased value (CTC, 2012).

The use of sugarcane by-products as an energy source could affect the creation of agricultural jobs hiring workers dismissed by the mechanization of the harvest (Smeets et al., 2008). There would also be an increase in industry labor demand. The exact impact of the use of the sugarcane straw for energy generation will depend on the technology and supply chains adopted.

- *Agronomic effects from straw left in raw sugarcane fields*

The harvest of raw sugarcane leaving behind the dry leaves and tops on the field is a system called green cane management. This blanketing influences the whole production process of sugarcane, affecting yields, fertilizer management and soil organic matter dynamics (Galdos et al. 2010). Some of the potential advantages of this system are (i) the protection of the soil surface against erosion caused by rain and wind, (ii) reduced soil temperature variations, (iii) increased biological activity in the soil, (iv) increased water infiltration into the soil, (v) reduction in water evaporation from the soil surface, and (vi) weed control (reduction in the use of herbicides) (Hassuani et al., 2005).

Some potential disadvantages include (i) increased fire hazards after the harvesting period, (ii) difficulties with mechanical cultivation and selective weed control, (iii) discontinuity of sprouts in the line of cane, causing a reduction in cane yield under certain conditions, and (iv) increased pests (Hassuani et al., 2005). In order to find the optimum amount of residues to be left on the field, it would be necessary to do a comprehensive study taking into consideration specific conditions of the production systems such as: soil type, sugarcane species, weather, sugarcane age, etc. According to CTC (2011), 50% of the straw left on the fields would be a suitable percentage to ensure the recovery of nutrients while the other 50% could be used for energy generation.

- *Qualitative changes in the rural worker profile demanded*

Only in the state of Sao Paulo the production of sugarcane mechanically harvested is expected to exceed 400 million tonnes by the harvest 2014/15 (UNICA, 2010). It is estimated that by that year the needed number of technical operators with specific qualification skills would be approximately 59,500 (UNICA, 2010).

The mechanization of the sugarcane harvest could foster an improvement in the public perception of the labor conditions of the industry. Currently some countries (e.g. Germany) are defining their energy strategies (UNICA, 2011). According to UNICA (2010), Germany was the first country to create sustainability criteria for the importation of biofuels[8]. The harvesting mechanization and the work quality improvements associated with it are not intrinsically linked to the compliance of potential social international sustainability criteria. The non-compliance of labor agreements or excess in the conventional workloads could take place in the sector regardless of the harvesting method adopted by a specific sugarcane producer. In general, adequate work conditions complying with national legislation and international sustainability demands could eventually tackle international trade barriers, bringing economic gains for the producers. Brazil has already launched a number of initiatives to improve the working conditions of the workers of the sector (Sect.6.2).

- *Cost and time reduction in the harvesting activity*

Harvest mechanization requires certain physical, technical, and productivity specifications in order to justify the use of machines which cost should not exceed the costs of the manual harvest (Plec et al., 2007). The mechanical harvest has the advantage that, contrarily to manual harvesters, can be carried out continuously 24 hours a day. Carrara (pers. comm., 2011) noted that the price of one ton of sugarcane is around R$62 while the cost of harvesting sugarcane mechanically is approximately R$15/ton and ca. R$21 when harvested manually (ca. 24% and 34% respectively from the total sugarcane cost). These cost estimations take into account the whole harvest operation (cut, loading, and transport operations). The cost difference between both systems is R$6/tonne which represents a 28.5% difference for this specific case study. Another report from the same sugarcane mill calculated the cost difference of both systems excluding the transportation costs. Carrara (2009) suggested that the average cost of the sugarcane was R$8.98/tonne when harvested mechanically while it was R$14.43/tonne when harvested manually only considering the cut and loading operations. The cost difference of these harvesting systems in this case would be ca. 38 %.

One possible disadvantage associated with harvesting cost reductions is the increased pressure to the manual harvesters in order to occupy the remaining positions. The productivity of the

[8] In 2008 the European Union sustainability standards (EU RES) were launched. Nevertheless, since 2007 Germany drafted its own act on requirements for the sustainable production of biomass for use as biofuel (Biomass Sustainability Order – German designation BioNAchV). These standards are currently not in implementation (EC, 2009).

machines has been used as benchmark for the productivity of the manual harvesters in the sugarcane mills (Silva, pers. comm., 2011). Currently, the non-compliance of production targets set by the employers can lead to the discharge and replacement of the workers (Parra, 2009).

- *Unemployment as a result of reduced demand for manual sugarcane harvesters*

Estimates about the reduction of the job positions caused by the mechanization can be found in the literature (Chapter 6). UNICA (2010) forecasted that by the 2015/16 harvest the jobs associated with the manual harvest will virtually disappear in the state of Sao Paulo. This would represent a loss of 189,600 jobs associated with the manual harvest compared to the number of manual harvesters employed in the harvest of 2006/07 (Table 12).

Table 12: Evolution of the number of workers of the sugarcane agro-industry. Sao Paulo, 2006/07, 2010/11 and the projection for 2015/16

	2006/07	2010/11	2015/16
Sugarcane production (million tonnes)	299	370	457
Mechanical harvest area (ha)	40%	70%	100%
Jobs:			
Manual harvest	189,600	107,400	0
Mechanical harvest	15,500	30,800	59,500
Industry	55,300	62,600	68,300
Total	260,400	200,800	127,800

Source: UNICA, 2010

The industrial jobs associated with the production of sugar and ethanol are expected to grow 23% and the jobs associated with the mechanical harvesting operations will grow ca. fourfold compared to 2006/07. The potential to reallocate the workforce released in the mechanical harvesting activities has been estimated at 20% (Smeets et al., 2008).

Based on these findings it is possible to conclude that mechanization will result in cost reductions and possibly higher productivity, thus making the industry more competitive. Furthermore, the mechanization is expected to have positive impacts on the environmental dimension of the ethanol sustainability as it will avoid the need of the burning practice besides the additional advantage of enabling the use of the sugarcane trash to generate energy. This latter development could have economic and environmental benefits. The modernization of the agricultural practices will also lead to challenges, mainly of social nature. The following chapters will focus on the labor market dynamics of the sugarcane agro-industry.

Chapter 4

4. Methodology

The Human Capability Framework (HCF) is as a holistic analysis tool to approach diverse factors influencing human capability and capacity within labor markets (Tipples, 2004). As will be described in this chapter, the HCF has a wide range of uses and applications. Furthermore, it can be scaled to suit applications ranging from regional to national or for specific sectors.

Within this Ph.D. thesis, the framework was used specifically to present a review of the Brazilian sugarcane agro-industry and to illustrate the current complex dynamics undergone by its labor market. This framework was selected because it supports the identification of influencing factors that affect the transition that the sector is undergoing. Sect. 4.1 will summarize the background and major characteristics of the framework. Sect. 4.2 will mention the use of the tool for policy design and highlight its importance as research tool. Sect. 4.3 continues with an explanation of the rationale behind its selection. Sect. 4.4 concludes the chapter with a representation of the Brazilian sugarcane agro-industry through the HCF.

4.1 Human Capability Framework

The New Zealand Department of Labor developed and launched in 1999 the Human Capability Framework (HCF) (NZ-DoL, 1999). The key objective of the HCF was initially to provide a conceptual framework for assessing the dynamics and forces of the labor market (Barker et al., 2009). This development induced a focus change of the Department of Labor since the HCF recognized a major significance associated with the social aspects of the labor market and not just its economic aspects (Edkins, 2003). When linking social and economic issues, the investigation, description, and discussion of labor market dynamics, labor market problems, and possible solutions could be done more comprehensively (NZ-DoL, 1999).

The HCF provides an interdisciplinary view of labor markets since it provides "an integrated view of key economic and social objectives and an understanding of the role of the labor market in achieving them" (Tipples, 2003; Bartley et al., 2001).

According to the NZ-DoL (1999), the HCF consists of three main components: capacity, opportunity, and matching. Capacity refers to the knowledge, skills, education, training, abilities, and attitudes that a worker possesses. In other words, it refers to what people are able to do (Edkins, 2003). When an individual uses these set of abilities, he/she can take advantage of the opportunities available for him/her in the labor market. Opportunity refers to the choices available for social actors to use their capacity as a means of gaining personal or financial reward. The demand side is strongly influenced by structural and institutional factors, as it is being influenced by state action (Murray, 2004). The matching element links both parts: capacity and labor maket opportunity. It encompasses a set of processes that consider the influences of these elements in each other (NZ-DoL, 1999).

The HCF acknowledges that employment is not only a consequence of economic transactions but also on-going social relations (Tipples, 2003). As the HCF also depicts the importance of the networks in which individuals are involved and which have an effect on their aspirations and preferences, the framework allows a holistic approach (Bartley et al., 2001). The NZ department of labor (NZ-DoL, 1999) sketched some of the contributing factors, even when it acknowledged that these factors vary from situation to situation (Fig. 25).

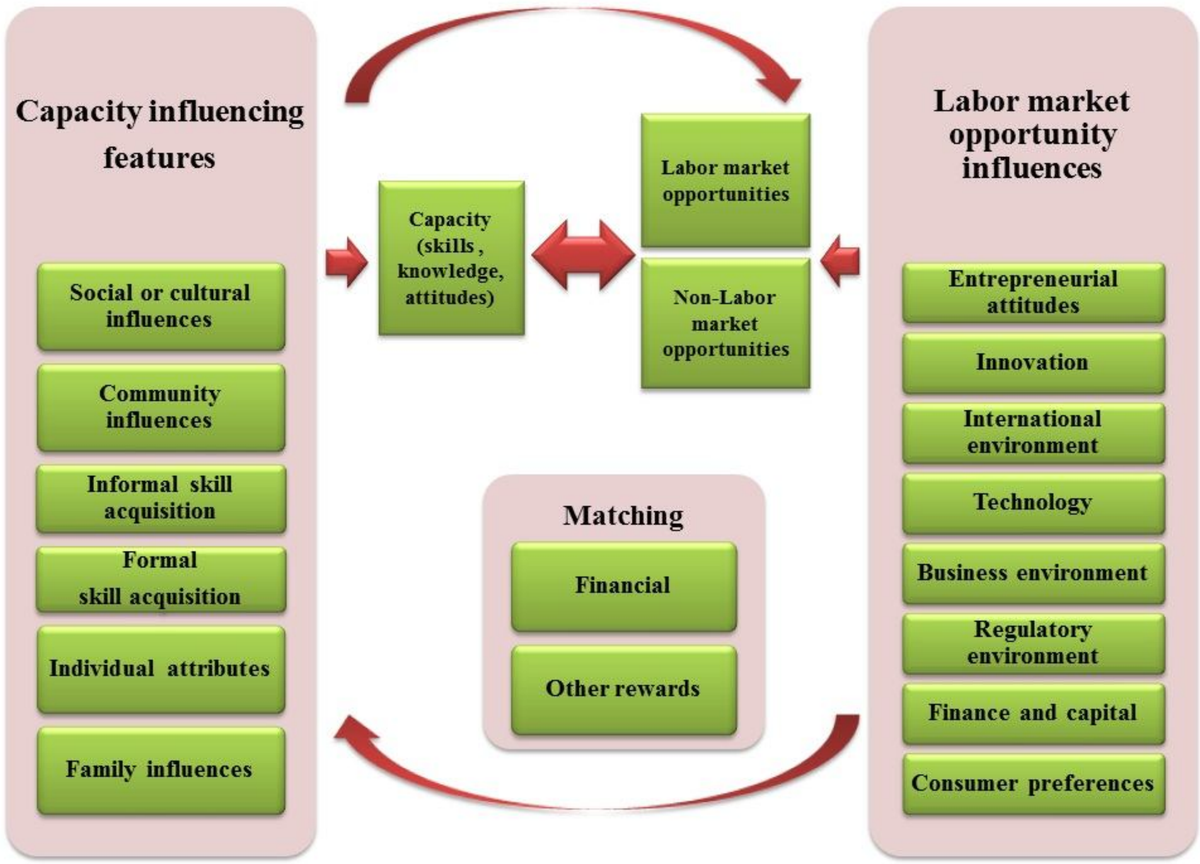

Fig. 25: Human Capability Framework diagram
Source: Adapted from NZ-DoL, 1999

From a classic economic viewpoint, the capacity term would be comparable to supply. Likewise, the opportunity term could be viewed as the demand for workforce. The HCF concepts of capacity and opportunity incorporate wider issues (Edkins, 2003).

The HCF is not quantitative. It does not intend to quantify the factors associated with the labor market dynamics (Tipples, 2004). The framework is designed to portray key economic, social and political components of the labor market dynamics and the interactions between these factors. Aspects that could be taken into consideration are the international environment, technology, the business and regulatory environment, and finance and capital (Murray, 2004). Furthermore, government policies, institutional arrangements, organizational practices and collective and individual behaviors have impacts on the labor market dynamics (Bryson, 2010).

4.2 Applications using the Human Capability Framework

In relation to the use of the HCF for policy creation, the NZ Government applied the HCF to create an organizing and analytical framework for the NZ Government's employment strategy. This strategy emphasized the need for sustainable employment and productivity. Other examples of the use of HCF in New Zealand include the Government's Interagency Skills Action Plan, which focused on measures to address skill shortages (Barker et al., 2009), and the government's policy advice on new skilled immigration and the Department of Labor's attempt to incorporate disadvantaged groups into the labor market (Tipples, 2004).

The HCF has also been used and adapted by other government agencies in New Zealand such as the Career Services, the Ministry for Agriculture and Forestry and the Ministry of Women's Affairs (Barker et al., 2009). The NZ Ministry of Women's Affairs used the framework to discuss the pay equity matter. The Ministry noted in one of its reports that a fair assessment and rewarding of skills should be part of human capacity building towards a skill-based, innovative, inclusive society (NZ - Ministry of Women's Affairs, 2002).

Besides being used at the government level, the HCF has also been used by regional government entities. For instance, the Cantebury Development Corporation applied it in the development of a document about the workplace situation in 2010. The application of the framework resulted in an analysis of the risks and opportunities of the labor market of Canterbury in 2010 (Tipples, 2004).

The HCF has also been used as a research tool for analyzing employment participation and labor supply problems in diverse industries and regions. A project named "Developing Human Capability" was carried out by researchers from Victoria University's Industrial Relations Department and Massey University's Department of Human Resource Management. The HCF was also used to design a research framework to investigate employment and labor supply problems in primary production and how to tackle them (Morris et al., 2001). The framework has also been applied to the dairy industry in order to predict likely future employment problems (Tipples et al., 2004).

After 2004 the HCF fell into disuse within the Department of Labor, because of changes in departmental leadership (Barker et al., 2009; Tipples, pers. comm., 2011). Although its importance has receded, government documents still make reference to it. For instance, the HCF was referenced in 2008 in the Ministry of Social Development's Social Report. Furthermore, it has been acknowledged that still today the HCF can provide a rational foundation for the research and analysis lines needed to develop well-rounded government policies relevant to the labor market (Barker et al., 2009).

4.3 Choice rationale

A key challenge regarding the workforce demand in the Brazilian sugarcane agro-industry is understanding and taking into consideration not only the skills and qualification level of an employee but also the social factors involved. The perception regarding a job opportunity could shape the mindset of potential employees affecting the matching process. The basis of these insights is deeply rooted to the background of the workers, the influence of their communities, and their expectations.

An advantage of the HCF is that it enables the consideration of formal and informal education. It emphasizes the importance of factors besides a person's skill set that influence their capacity in relation to employment opportunities (Edkins, 2003).

Edkins (2003) in his research work compared the use of the HCF and a neo-classical supply and demand model. It was stated that in a neo-classical supply and demand graph, the number of X (for instance, unskilled workers in an area) and the value Y (wage rates) should be reached to achieve the equilibrium point. Edkins (2003) suggested that this model assumed homogeneity of people's skills and mindsets. The HCF tackles this weakness by providing a more comprehensive analysis.

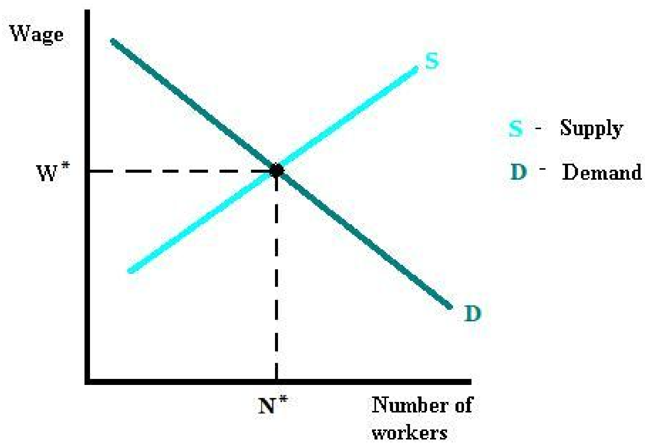

Fig. 26: Theoretical economic supply and demand model
Source: Latzko, 2006

The HCF could also be considered as a more robust tool compared to the narrower focus of the Human Capital Approach. Murray (2004) suggested that the HCF provides a useful counterbalance to the traditional Human Capital Theory mainly because it considers the importance of the demand side in the labor market dynamics. It was also highlighted that the framework enables the analyses of a labor market considering a wider context.

In order to approach the labor market dynamics of a particular case study using the HCF, it is important to define the context and the depth of the analysis (Tipples, pers. comm., 2010). Bryson & O'Neil (2008) believed that in order to identify and foster conditions for the optimal development of human capability in a sector, it is important to extend the scope. It was noted that to identify optimal conditions for developing human capability is not enough but it is also desirable to surface what are the institutional, organizational and individual drivers and barriers.

One of the objectives of this dissertation is to use the HCF as a research tool to contribute to the evaluation of its application in diverse settings as it has been recommended (Tipples, 2002). This Ph.D. thesis will contribute to prove the suitability of the framework for a specific research line aimed at making suggestions about its use and possible improvements.

4.4 The Brazilian sugarcane agro-industry using the HCF

The HCF is used to determine the elements to be analyzed for developing labor market interventions. For this research project, a sample of stakeholders was selected. In order to enhance the applicability of the framework, its original elements were used as a basis to be compared to the features that the involved social actors considered relevant for this specific case study.

A sample is a set of subjects selected from a population (Miller & Salkind, 1991). For this dissertation, the sampling method was the interviewing of diversified social groups[9]. Hence, of the three commonly used sampling methods (random sampling, stratified sampling, and judgmental or purposive sampling) the third approach was chosen. According to Miller & Salkind (1991), in situations where practical considerations impede the use of probability sampling, researchers can pursue a representative sample by non-probabilistic means. The judgmental or purposive sampling method looks for subgroups and restricts observations to it alone. The conclusions from the data obtained are subsequently generalized to the total population of the social group[10]. A list of key social actors that were identified as being directly involved in the problem analyzed is shown in the Table 13.

9 A social group can be defined as two or more individuals who perceive themselves to be members of the same social category (Tajfel, 2010).
10 Sampling errors and biases cannot be computed for such samples.

Table 13: List of interviewed stakeholders

- **Government:** Ministry of Agriculture and Livestock (MAPA)

Person interviewed: Director of the Sugarcane and Agro-energy Division.

- **Industry representatives:** Brazilian Sugarcane Industry Association (UNICA)

Person interviewed: Corporate Responsibility Consultant.

- **Employers:** Sugarcane mills. *SJC Bioenergia Group.*

Persons interviewed: Human resources, agricultural and industrial managers from *Usina São João* (Araras, Sao Paulo) and *Usina São Francisco* (Quirinopolis, Goias).

- **Rural worker's organizations:** Federation of Rural Salaried Employees of Sao Paulo.

Persons interviewed: President, general secretary, other functionaries and a lawyer from FERAESP. Municipal workers' union leaders.

- **Non-governmental organizations:** Repórter Brasil.

Persons interviewed: Coordinator and collaborators of the Biofuel Watch Center.

- **Rural workers**

Persons interviewed: manual sugarcane harvesters, mechanical sugarcane harvesters, other agricultural workers including agro-chemical appliers, family agriculture workers.

- **Qualification entities:** RenovAção Program, Governent of Brazil, SENAI.

Persons interviewed: Representatives of different qualification programs.

- **Research centers**

CENBIO (Brazilian Reference Center on Biomass), CTBE (Brazilian Bioethanol Science and Technology Laboratory), CENA (Center for Nuclear Energy in Agriculture).
Persons interviewed: Researchers working in various lines of researchF.

- **Independent researchers**

Each of the stakeholders interviewed was asked to identify which aspects in his/her opinion could influence the labor market of the sugarcane agro-industry as a consequence of the mechanization of the harvest. Each stakeholder was also asked to explain the reasons behind their answers.

The interviewed stakeholders pointed out that the elements which could exert an influence (positive or negative) on the workers' chances of remaining in the sector after mechanization were: (i) their background, (ii) whether they were affiliated with the workers' union, (iii) their formal and informal skills, (iv) demographics, and (v) their productivity.

On the other hand, the interviewed stakeholders also identified the elements that could determine the qualitative, quantitative, temporary, and geographical characteristics of the labor market due to the mechanization of the harvest. The elements identified by the stakeholders were: (i) national and international market developments, (ii) environmental and labor legislation, (iii) current agricultural trends, (iv) working conditions, (v) the pace of mechanization, and (vi) the Agro-environmental zoning.

It seemed to be a consensus among the stakeholders interviewed that the key feature to linking the capacity and the labor market would be the qualification of the workforce. The impacts of mechanization on the characteristics of employment were also considered as an important part of this study.

These interviews enabled the author to better understand the stakeholders' points of view and to compare this information with the original framework. Hence, it was possible to revise whether these elements were covered, or at least partially covered within the HCF. The influencing elements to be studied were re-defined leading to the construction of a new framework. This adapted version was constructed aimed at setting forth the state of the art of the stakeholders' situation understanding (Fig. 27).

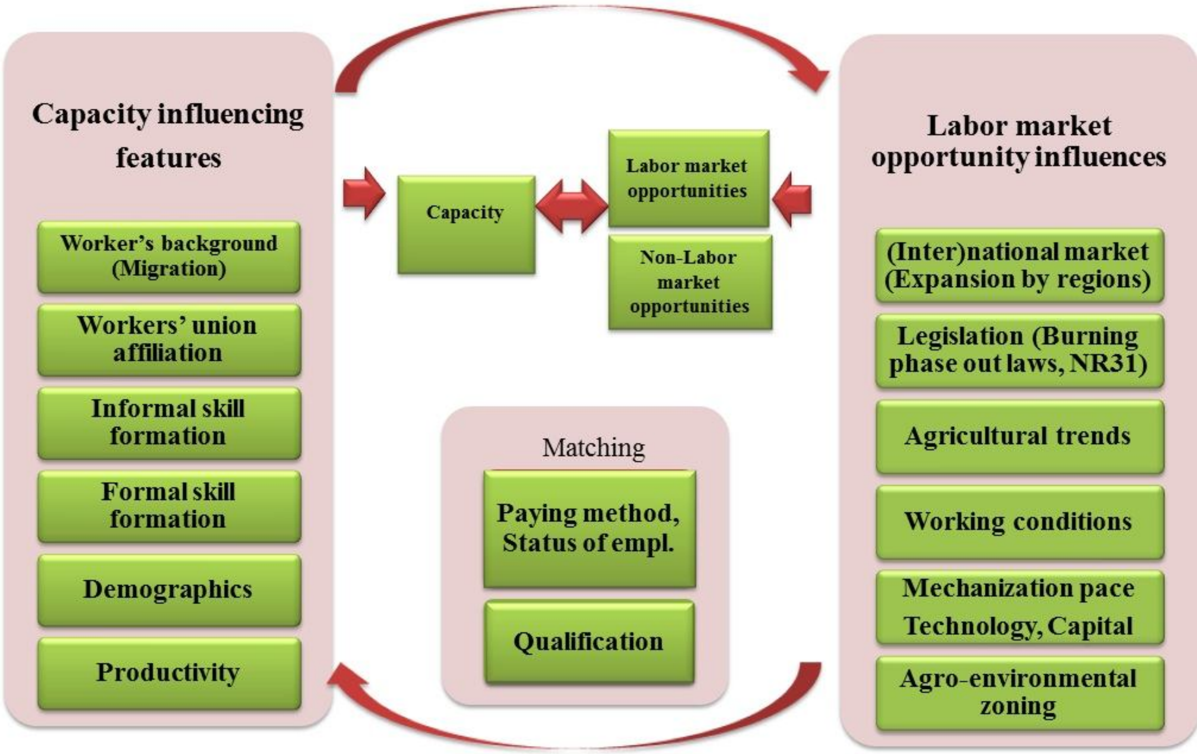

Fig. 27: The Brazilian sugarcane agro-industry viewed through the Human Capability Framework
Source: Research data

The Figure 27 illustrates the identified influencing features of the Brazilian sugarcane agro-industrial labor market but does not show the interaction among them beforehand as in the original framework. The cause and effect relationships among these elements were identified after the analysis of each one of them and are shown in Chapter 7.

When carrying out the field interviews, it was possible to note that the context and affiliations in which the social actors are embedded have a strong influence on their perception of mechanization. According to Tajfel (2010), group behavior could be considered the expression of cohesive social relationships between individuals which regulate their opinions and conduct in matters of common interest.

Even when the HCF is unable to quantify the impact of each factor in the future developments of the sector, it provides an intelligible basis for research that could affect the development of well-rounded policies (Tipples, 2004).

Chapter 5

5. Capacity influencing features

The salaried labor market of the Brazilian sugarcane agro-industry is heterogeneous. The objective of this chapter is to analyze each of the acknowledged features that influence the capacity side of the framework constructed. An exploration of these elements will enable a better understanding of the workforce's profile and its evolution over time. Sect. 5.1 analyzes the temporary migration flows and its drivers and consequences. Sect. 5.2 explores the workers' union movement organization and the influence that it had in recent developments. Sect. 5.3 covers the informal skills (gained empirically) of the rural workers and describes their main activities. Sect. 5.4 gives an insight into the formal skill formation of the workers and its evolution and regional differences. Sect. 5.5 analyzes some key demographic characteristics of the group under study. Sect. 5.6 studies the increasing productivity trend and its relationship to remuneration gains. Sect. 5.7 finishes with a summary of the risks and opportunities detected in this Chapter.

5.1 Background (Migration)

According to Cover (2011), the migration of peasants from the Northeast to the Center-South of Brazil reached high numbers during the 1930s due to the industrialization of the Southeast. Between 1950 and 1980 more than 40 million people migrated from the rural areas to the cities (Milano & Pera, 2011). From 1964 to 1984 the Brazilian military regime granted heavily subsidized rural credits in order to modernize the agricultural sector (Parra, 2009). The agricultural modernization has been linked to the evolution of the exclusionary and concentrated land structures as small rural properties were gradually incorporated to larger ones, sometimes expelling rural workers. During the 1970s and 1980s the sugarcane expansion aggravated land tenure conflicts (Smeets et al., 2008). Smeets et al. (2008) made reference to reports of cases in which farmers had been forced to leave their lands by economic and legal pressure, and even by direct physical intimidation. Other cases of rural conflict and violence have been documented by various authors (Kohlhepp, 2010; Alves, 2009; MST, 2012). The expulsion of rural populations is one of the drivers of the migration flows of workers that come to work in the sugarcane fields in Sao Paulo (Silva, pers. comm., 2011).

In general, land tenure is a significant problem in Brazil since landless people are the largest share of the rural poor population (Smeets et al., 2008). In 2009, IBGE disclosed in its Agricultural Census that land concentration and regional inequality in Brazil had worsened in the last decades. The Gini Index[11] for the agricultural structure of the country was 0.872 in 2006, when it was 0.857 in 1985 and 0.856 in 1995 (IBGE, 2009). It was also reported that rural settlements of less than 10 hectares occupied less than 2.7% of the total area occupied by rural settlements while farms of more than 1,000 hectares made up more that 43% (IBGE, 2009).

For the sugarcane agro-industry, land concentration is a major challenge due to the extent of occupied areas and the level of existing vertical integration regardless of the existence of thousands of sugarcane suppliers and tenants (BNDES/CGEE et al., 2008). According to IBGE (2009), in 2007 90.4% of the occupied persons in the sugarcane culture in Brazil were employees and 1.2% were employers. The other 8.4% were independent producers, producers for self-consumption, and occupied persons without remuneration. In Sao Paulo state, the percentage of employees reached 97.3% while 1.4% were employers. In the North and Northeast regions, these figures were respectively 85.8% and 1.3% and in the Center-South 93.7% and 1.1% (IBGE, 2009).

Available literature offers various theories that try to give an explanation of the migration flows in Brazil. Some of the drivers identified are: low land productivity associated with soil and climate, low levels of education, lack of infrastructure, general economic stagnation and low income per capita in the regions of origin (which made difficult to create a consumer market), lack of job opportunities, regional differences in salaries (Table 14) (Cover, 2011; Moraes et al., 2008).

Table 14: Regional average salaries (in Brazilian Reais) of sugarcane workers and other crops in 2007

Crop	North / Northeast	Center-South	Variation (%)
Sugarcane	410	708.5	73
Soy	782	803.2	2.7
Coffee	250.1	485.7	94.2
Corn	189.6	344.4	81.6
Manioc	198.2	375.4	89.4

Source: Oliveira, 2009
Note*: in R$ from August 2008 using the Consumer National Price Index (INPC) as deflator

The Table 14 shows that this trend is not exclusive to sugarcane. It is interesting to note that the regional variation in average salaries is as high as 200% when considering rice and as low as 2.7% when considering soy. This phenomenon might be related to the degree of mechanization of each crop (Sect. 6.2).

[11] The proximity of the Gini Index value to 1 indicates the degree of land concentration.

The average remuneration of the sugar and ethanol supply chains also shows regional variations (Table 15). As for sugarcane, their salaries are below the Brazilian average in the North and Northeast regions and above average in the Center-South. The best performance of this indicator was observed in Sao Paulo.

Table 15: Regional differences of the average salaries (in Brazilian Reais) of the sugarcane agro-industry workers in 2007

Activity/Region	North/Northeast	Center-South	Sao Paulo	Brazil
Sugarcane	427.10	713.8	818.8	586.1
Sugar	847.6	1,363.1	1,538.6	1,201.6
Ethanol	512.8	1,319.2	1,585.3	1,254.8

Source: Adapted from Hoffmann & Oliveira, 2008a
Note*: in R$ from August 2008 using the Consumer National Price Index (INPC) as deflator

The regional differences in salary within the sugarcane agro-industry follow the trend of the entire Brazilian economy. The Fig. 28 shows the evolution of the average monthly income of all the remunerated jobs in Brazil.

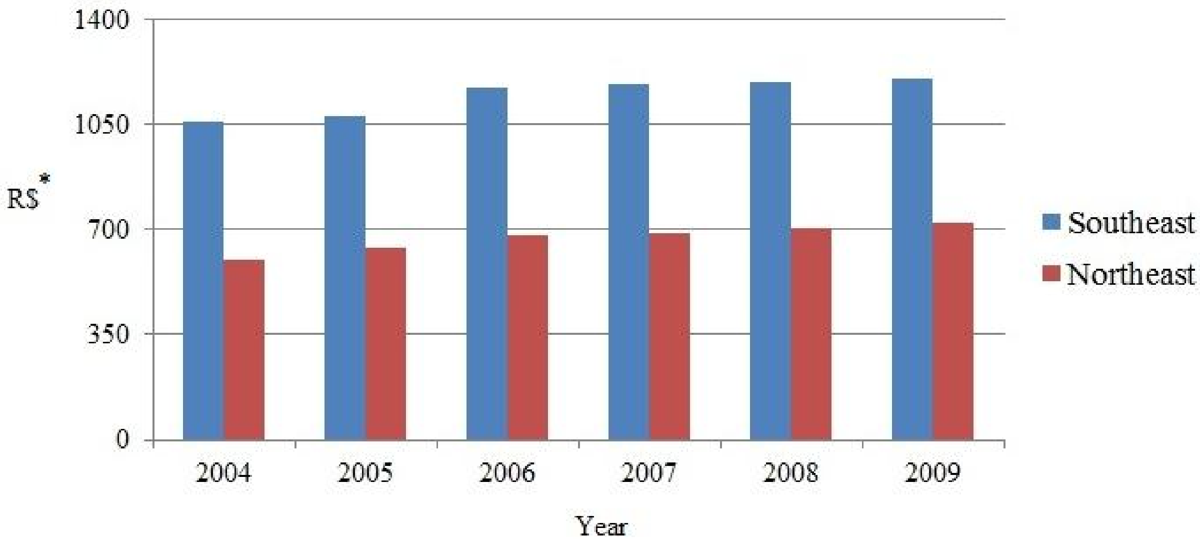

Fig. 28: Evolution of the average monthly income of all the jobs of all occupied persons. Southeast and Northeast regions, 2004-2009
Source: PNAD, 2004-2009
Note*: In R$ from 2009 using the Broad National Index of consumer prices (IPCA) as deflator

UNICA reported that in the harvest 2006/07 ca. 40% of the sugarcane harvesters in Sao Paulo were migrants coming from other Brazilian states. According to Alves (2009), from the 180,000 – 250,000 manual sugarcane harvesters working in Sao Paulo, approximately 70% were "*oscilating migrants*[12]". According to Pastoral do Migrante, by that time there were 70,000 migrant workers in the Riberao Preto area alone (Alves, 2009). Some of the sugar mills that hire migrant workers had adopted the strategy to recruit the workers in their places

[12] An *oscillating* or *pendular migrant* is defined as a worker that travels to live and work in another area (in this case) during the sugarcane harvesting season and go back to their areas of origin afterwards.

of origin. These workers usually come from the poorest regions of the country, for instance the Jequitinhonha Valley in Minas Gerais state, Maranhão, Piauí and other states of the Northeast (Moraes, 2010). In 2008, Pastoral do Migrante carried out a survey at the Jequitinhonha Valley and found out that for some municipalities the share of migrants that left to Sao Paulo during the sugarcane harvesting season was as high as 51% (Minas Novas), 43% (Francisco Badaro), and 42% (Virgem da Lapa) of the total population (Pastoral do Migrante, 2008).

Usually, the migrants travel to the plantation with their job guaranteed and, depending on their productivity, their income could be higher than other occupations (Moraes & Figueiredo, 2008). These workers have a temporary contract for the harvesting season and in order to be hired the next term, they must go back to their cities of origin, have a good performance and attitude evaluation and be in good health according to the doctors hired by the mill (Silva, 2011).

These seasonal migration flows have implications for the destination "*dormitory cities.*" Moraes et al. (2008) carried out field research and reported that the population of the dormitory cities has diverse opinions regarding the presence of the migrants that go there for the sugarcane harvest. On the one hand, some residents argued that the migrant workforce stimulated the commerce of the region. On the other hand, other residents reported problems associated with their presence such as overcrowding of the health and transportation systems. The Ministry of Employment in the states of origin is responsible for the supervision of the migration flows. The employer is responsible for providing accommodation, food, and transportation to the workers. In the last years, various reports drew the public attention towards mills with deficient accommodation and transportation systems (Reporter Brasil, 2010). An industrial manager of a sugarcane mill noted in a personal interview that there is currently a growing trend to discontinue the hiring of migrants and hire only locally in the production region. This is especially the case in the Center-West, where an expansion is taking place (Carrara pers. comm., 2011).

Migration as a capacity influencing feature

The background of the worker (whether or not he/she is a temporary migrant) will certainly influence his/her perspectives for the new labor market arrangement. Qualification efforts carried out by the sugarcane mills, the federal government and the industry representatives are focused on: (i) satisfying the workforce requirements of the industry, and (ii) compensating some of the unemployment in the main sugarcane producing regions (e.g. Sao Paulo) (Chapter

7). As not being eligible for taking part of a qualification initiative, the temporary migrants would have the option of either going back to their region of origin or try to relocate themselves into other sectors (agricultural or not) in the destination region. Moraes & Figueiredo (2008) noted that due to the adverse conditions in the regions of origin of the migrants, it is likely that part of the dismissed workers will keep their migration trend.

When asking migrant harvesters in personal interviews what option would they prefer, their opinions were polarized. Some of them noted that if they went back to their regions of origin they would encounter difficulties to find a remunerated job and if they did, most likely would not get the same salary as the one they get as manual harvesters in Sao Paulo. Therefore, they would prefer to try to find another option in Sao Paulo. On the other hand, other workers noted that to migrate to the urban areas in the productive regions did not make any sense without a job. Other topic of distress is the negative impact in the origin cities as they stop receiving the income of the migrants. According to Moraes (2010), this income is very important in the local economies of some populations in the deprived regions of Brazil.

5.2 Workers' union affiliation

In Brazil the workers have the right to organize themselves and negotiate their working conditions under the labor laws (CLT - *Consolidação das Leis do Trabalho*) (Sect. 6.2). The organization of rural workers started in Brazil in the 1950s in the context of agricultural modernization (Moraes, 2009; Alves, 1991). In Brazil, there is no competition between unions. Therefore, the options for workers are either to be associated or not. Table 16 shows the total number of salaried sugarcane workers and the percentage of them that were affiliated with the workers' union in 2006.

Table 16: Proportion of union affiliation of sugarcane workers. Brazil, by region, 2006

Region	Number of employees	Percentage of union affiliation
Brazil	532,263	36.7%
North-Northeast	263,291	40.7%
Center-South	268,972	32.7%
Sao Paulo	156,279	36%

Source: Adapted from Moraes, 2009

The Brazilian workers' unions are organized on three levels: municipal, state, and national. Workers' union leaders can represent one or several neighboring municipalities. The unions are usually associated with the state entity (Federation). Several Federations are frequently affiliated with the National Confederation. In Sao Paulo state, the Federation of Rural

Employees of Sao Paulo[13] (FERAESP) and the unions of rural workers are the representative entities of the rural workers. The union structure and a significant share of the federal activities in the area are financed by mandatory taxes charged to employees and enterprises. This levy is distributed as follows:

I. For the employers (Law No. 11.648/08):
   a) 5% corresponding to the confederation.
   b) 15% for the federation.
   c) 60% for the relevant trade union.
   d) 20% for the “special account of employment and salary.

II. For workers (Law No. 11.648/08):
   a) 5% for the corresponding confederation.
   b) 10% for the unions’ central.
   c) 15% for the federation.
   d) 60% for the corresponding union.
   e) 10% for the special account for employment and salary.

The outbreak of strikes in the 1980s caused changes in the workers’ unions strategies and culture (Milano & Pera, 2011). During the strike in Guariba in 1984 the rural sugarcane workers organized themselves to protest against the harvest system in which they had to harvest 7 rows of sugarcane instead of 5 (Sect. 5.3). After this event, other strikes took place involving workers from various regions, states, and cultures. In this same year sugarcane harvesters from Rio de Janeiro, Minas Gerais, Mato Grosso do Sul and Parana carried out strikes (Alves, 1991). The decade saw dozens of strikes, including some general ones. Important improvements in the working conditions of the rural sugarcane workers have been attributed to these social movements. These improvements included better transportation, increase in the proportion of formal workers in the sector, and protection equipment (Milano & Pera, 2011; Silva, pers. comm., 2011; Neves, pers. comm, 2010; Aguiar, pers. comm., 2010).

According to Milano & Pera (2011), the rural salaried workers are a category of workforce with specific characteristics that hinder a syndical education. The irregular nature of the agricultural jobs and the low literacy levels were mentioned as an explanation for this statement (Sect. 5.4).

Cacciamali (2005) tried to identify the causes of the bargaining power loss among Brazilian workers’ unions. Some of the factors identified by the author were the substitution of employees, high levels of unemployment, multitasking during the execution of the activities, outsourcing, and the work relations of the informal sector.

[13] Federação dos Empregados Rurais do estado de São Paulo.

Milano & Pera (2011) suggest that the mechanization of the sugarcane harvesting operation could also lead to a decline in the bargaining power of the rural workers because this will reduce the number of employees. Moraes (2007a) suggested that a better organization of the workers' unions can be associated with a higher influence in decisions and bargaining power for the salary negotiation related to the mechanization, accelerating it.

Currently, the workers' unions still aim to improve working conditions and salaries of rural workers but also are actively dealing with other topics such as requalification and sustainability (FERAESP, 2012).

Workers' union affiliation as a capacity influencing feature

The role of workers' unions in the new labor market structure caused by the mechanization will depend on their degree of organization. The cohesion of the unions could improve its degree of influence in the decisions of other stakeholders. Interviews with workers' union leaders revealed that there is a belief that even when mechanization is a widespread practice, a small amount of manual sugarcane harvesters will still be necessary. They consider the role of the workers' union important in negotiating work conditions, salaries, health plans, etc.

Contrarily, one interviewed worker noted that there is fierce competition for placement in the qualification programs offered by the industry. Even when the program had defined selection strategies, some vacancies for these courses were assigned based on cronyism without taking into consideration the abilities of the workers to perform the new occupations. It was noted that "to be affiliated or to have a good relationship with the workers' union" would facilitate access to qualification opportunities. Qualification strategies should try to avoid this situation, standardizing the process in which the workers are recruited and selected.

An interview with the leader of the FEARESP revealed that the importance of the workers' union to the new labor market dynamics will be to protect the interests of the rural workers, mainly through promoting the access to land.

5.3 Informal skill formation

Producers wish to harvest the sugarcane during the best maturation season. Therefore, they plan the sugarcane fields searching for sugarcane varieties and agricultural practices which would enable them to obtain the highest quality levels in the beginning, middle, and end of the harvest period. The large producers usually develop work logistics so that they can operate practically all the harvesting period (Sachs, 2007). Manual harvesting is a process in which the worker cuts the sugarcane along a 6 m wide path (the length depends on the performance of the harvester) containing usually five rows of sugarcane (lines in which the sugarcane is planted with 1.5 meter distance among them) (Reporter Brasil, 2010). This activity is organized in groups of about 30 or 40 workers. Despite this organization, the work involves individual activities (Parra, 2009).

The performance of the manual harvesters is linked to their empirical learning process of carrying out their tasks. The main activities are described in the work of Cardoso (2010). After removing the straw remaining after the burning, the worker surrounds with his arms as much sugarcane as possible (from 5 to 10 stalks). Afterwards he/she leans his/her body to strike the base with his/her knife (*machete*) until he/she is able to cut all the sugarcane embraced. It is necessary to cut the sugarcane as close to the roots as possible because the base contains most of the sacarose. On the other hand the workers have to be careful not to damage the root that would inhibit the further growth of the plant. The worker must cut the uppermost part of the sugarcane *(ponteira or palmito)* (Fig. 29). It can be carried out as soon as the sugarcane has been cut from the base. This operation could be done either when the stick is still in the hand of the worker or in the floor after being organized in rows[14]. The worker must be careful not to leave a lot of straw since it can cause reductions in the performance of the milling and not to cut too much as it might cause losses of material.

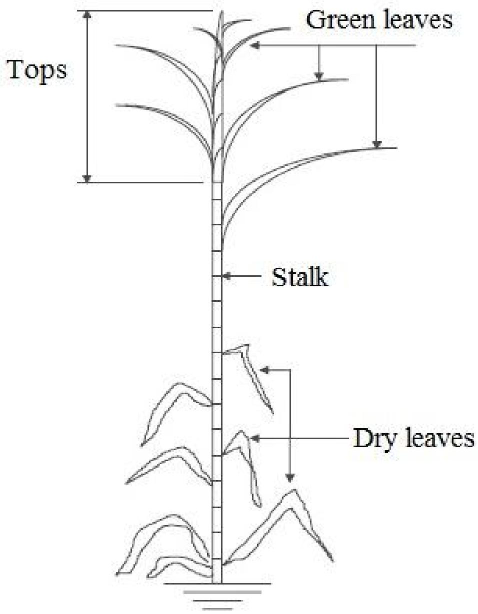

Fig. 29: Sugarcane plant parts
Source: Hassuani et al., 2005

14 In some mills, workers have to cut the tips in the air, in others he/she is allowed to cut it on the floor. In others mills, the harvester is allowed to cut down the tips in the middle row, where the cane is piled. In this case, after removing the tip, the worker has to separate them from the sugarcane piles at least one and a half meter (Alves, 2007).

The worker should orderly place the stalks in rows or piles separated from each other by one meter distance in the third or fourth line if the harvest was carried out in 5 or 7 lines so that the transportation machines can transport them to the mill.

Depending on the condition of the sugarcane, this procedure varies. When the sugarcane is standing (*cana em pé*) several sugarcane stems can be cut simultaneously. This is not the case when the sugarcane is "laid" (*deitada*) (if it falls on one side) or "rolled" (*enrolada ou bigolada*) (if it falls down in different directions).

The labor supervisors are in charge of observing the size of the sugarcane piles, the distance between piles (so that the machine is able to collect them), the removal of the tops, and the height of the sugarcane cut (Alves, 2007). It is common that labor supervisors punish mistakes with penalties (*ganchos*). The accumulation of penalties could imply that the worker is suspended from his/her work for up to three days (varying from employer to employer) (Aguiar, pers. comm., 2010). According to Goldemberg et al. (2008), controls, intensification of the work shifts, and the establishment of daily production targets were some of the aspects that have led to significant productivity increases.

According to Silva (2011), manual sugarcane harvesters usually come from families of farmers and usually start in agriculture at a young age. Therefore, even when these workers are illiterate or have only a few years of schooling, they fulfill the requirements of the employers in performing the physically demanding work of sugarcane harvest.

In order to cut 12 tonnes of sugarcane a day, a worker would have to walk more than 8 km, perform more than 130 thousand strikes with the knife (considering standing sugarcane from a first cut with high sugarcane density), carry the 12 tonnes of sugarcane in batches of 15 kg each in distances of 1.5 to 3 meters 800 times (Alves, 2007).

Ficcarelli & Ribeiro (2010) documented that the manual sugarcane harvest was physically demanding due to the posture required to carry out this task, the performance of repetitive activities, the transportation of heavy loads, and the prolonged exposure to sunlight. In addition to the physical hazards, Alessi & Navarro (1997) suggested that the sugarcane harvesters are daily exposed to chemical and biological hazards that could bring about health problems such as dermatitis, dehydration, cramps, dyspnea, infections in the respiratory tract, high blood pressure, spinal column, chest, head and lumbar pains and damages to the musculoskeletal system. Other research works also established a link between the manual harvest activities and negative effects on the health of the workers (Novaes, 2007; Rumin et al., 2008; Scopinho, 1999; Barreto & Junior, 2011).

Former sugarcane workers revealed to the author in personal interviews that after having worked for more than 10 years it is difficult to carry out basic daily activities because of the damages and pain on their wrists and arms. According to Silva (2007), depending on the workload, the working lifespan of the sugarcane harvesters could be shorter than that of slaves (10-12 years until 1850 and from 15-20 after some improvements in their work conditions). Nonetheless, manual sugarcane harvesters interviewed noted that harvesting sugarcane had advantages compared to other cultures in Brazil in terms of remuneration, share of formal jobs, etc. Also, they noted the advantages of having a work relation on a temporary basis since they could occupy themselves in subsistence agriculture with their families in the inter-harvest period (Sect.6.4).

The mechanization of the sugarcane operation will help to decrease the physical and chemical threats of the workers (Scopinho, 1999).

Informal skill formation as a capacity influencing feature

It could be assumed that the informal skills, good health conditions and vitality of these workers could help them find other jobs in agriculture. Personal interviews with workers' union leaders in Sao Paulo state revealed that a share of the workers that were dismissed from sugarcane harvesting is currently working in the production of oranges, coffee and potatos. The workers' union leaders and workers interviewed acknowledged their worry about the mechanization of these cultures as well, as the agricultural jobs are less as the time goes by (Sect. 6.3). It was also noted that the construction sector has also absorbed some of the dismissed workers probably motivated by projects in the energy, transportation and housing sector. Large scale events taking place in Brazil in the medium term, such as the Olympics and the Football World Championship will also increase the demand for civil construction workers (Silva, pers. comm., 2011). Nevertheless, in order to find a job in the construction sector, the rural wokers would have to acquire specific qualifications as well.

5.4 Formal skill formation

IBGE reported in 2010 that approximately 9% of the Brazilian population is illiterate (ca. 14.6 millions). The Paulo Montenegro/IBOPE Institute reported in 2009 that from the total persons from 15 to 24 years old, 52% was fully literate, 33% had basic literacy, 13% were functionally literate and 2% were illiterate.

The schooling levels of agricultural workers depend largely on their status. Basaldi (2007) documented that in 2005 14.2% of the permanent employees with an urban residence working in sugarcane agricultural activities had an average schooling of at least 8 years while the temporary urban, temporary rural, and permanent rural had lower percentages (9.7%, 7.4% and 5% respectively). These levels had positively evolved for all the categories of workers as these values were 1.5% for permanent workers with urban residence, 0.2% for temporary workers with urban residence, 0.3% for temporary workers with rural residence and 1.9% for permanent workers with rural residence in 1992.

During the last few years, there has been a positive evolution in the number of schooling years among the workers in the agricultural sector (Fig. 30).

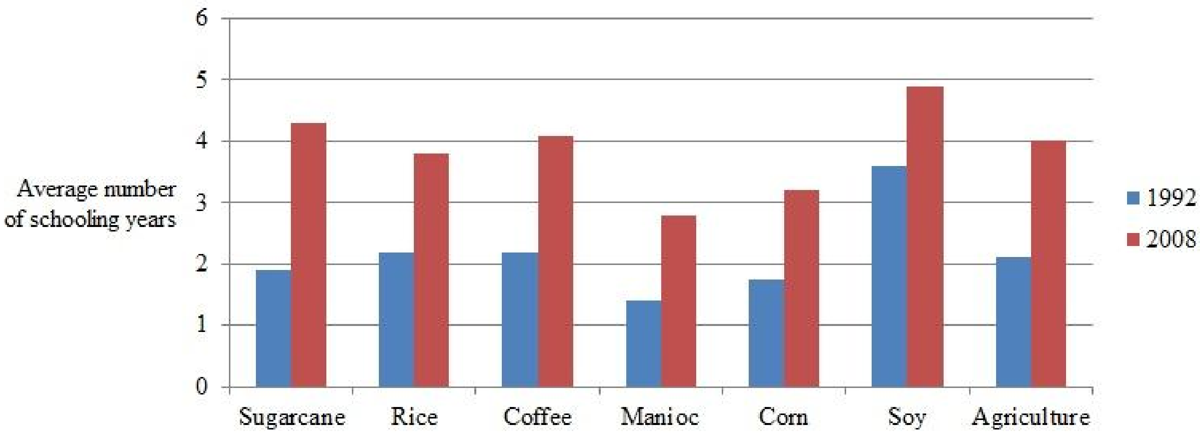

Fig. 30: Evolution of the average number of schooling years of the workers of sugarcane and other selected crops. Brazil, 1992 and 2008
Source: Adapted from data from PNAD, 1992 apud Oliveira, 2009 and PNAD, 2008, apud Moraes et al. 2011

The Figure 30 shows that the sugarcane culture had a higher schooling level average (4.3) in 2008 than the agricultural sector in general (4). This indicator was higher than for workers of rice (3.8), coffee (4.1), manioc (2.8), and corn (3.2) (Moraes et al., 2011).

The soy culture has the highest levels of formal education. This might be due to its high levels of mechanization. Mechanization of agricultural activities modifies the workforce profile of the sector, increasing the demand for a qualified workforce while reducing the demand for employees with low levels of schooling (Moraes, 2007). According to IBGE, in 2008 the percentage of machine operators in the entire agricultural sector in Brazil was 7%. The soy crop showed the highest percentage of machine operators from the total of agricultural workers with 44.3%. This indicator was 11.2% for sugarcane, which was surpassed by other crops such as rice (16.6%) and citrus (14.5%) (Moraes, 2010).

The average years of formal education of the sugarcane workers varies largely from one region to another (Fig. 31). In 2006 the Northeast had a high share of illiterate workers compared to other regions (26.2% for the Northeast, 2.68% and 2.47% for the Southeast and Sao Paulo state respectively) (Liboni, 2009).

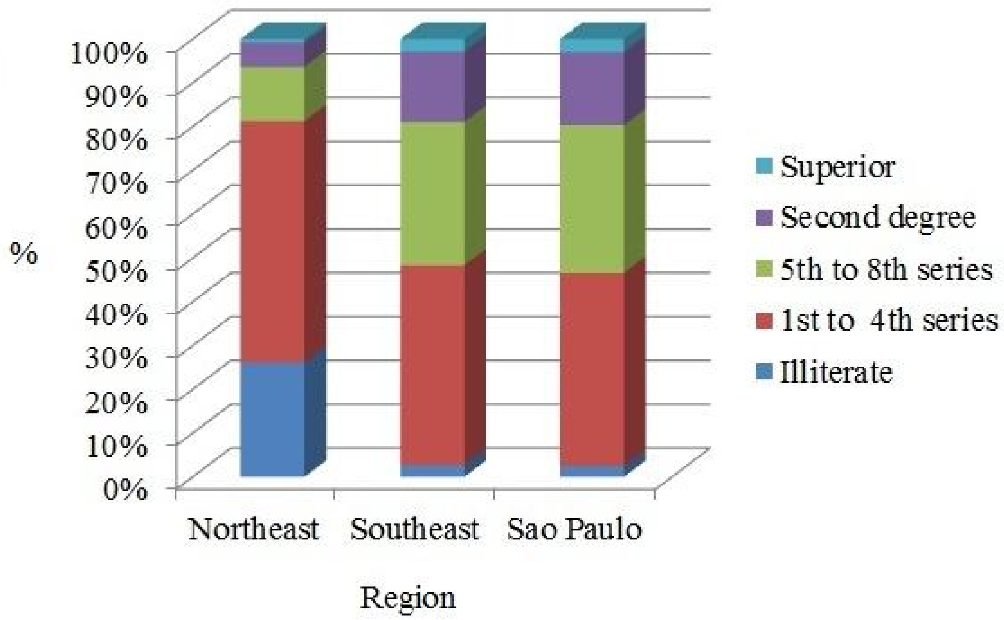

Fig. 31: Distribution of the formal education degree of the sugarcane workers. Brazil, by region, 2006
Source: Adapted from data from RAIS, 2006, apud Liboni, 2009

This tendency could be linked to the fact that illiteracy rates in Brazil vary largely among macro-regions (Table 17). The states with the highest illiteracy rates are Alagoas (22.5%), Piaui (21.1%) and Paraiba (20.2%). All three of them are located in the Northeast region.

Table 17: Percentage of illiteracy. Brazil, by region, 2010

Region	Percentage of Illiteracy
Northeast	17.7
North	10.6
Center-West	6.6
Southeast	5.1
South	4.7

Source: IBGE, 2010

According to PNAD, in 2008 the average number of schooling years among the sugarcane workers was 4.3. This indicator was higher in Sao Paulo state (5.5 years) than in the Center–South regions (5.2 years) and the North–Northeast regions (3.1 years) (Moraes, 2011).

The consensus in the literature seems to be that those with the lowest schooling levels are the most vulnerable to losing their jobs if mechanization takes place. For instance, Guilhoto et al. (2002) constructed an interregional input-output model for the sugarcane, sugar, and alcohol sectors in 1997 to predict the reductions of the workers employed in the sugarcane production. This study was based on three scenarios: (i) 50% mechanization of the harvest in the North-Northeast region and 80% in the Center-South without changes in productivity levels, (ii) assuming an increase of productivity of 20% for manual and mechanical harvesting, (iii) assuming an increase of productivity of 20% for all the regions except for the Northeast for which an increase in the productivity was calculated as 140% for the manual harvest and 20% of the mechanical harvest. This study concluded that from the 52-64% of the reduction of sugarcane workforce, the main decrease in direct employment would occur in the workers with up to three schooling years (44-48% of the total workers with less than 1 year of schooling and 40-42% of the workers between 1 and 3 years of study) mainly from the Northeastern region (Guilhoto et al., 2002).

The average schooling level correlates positively with workers' salaries (Moraes, 2007). This tendency appears to be maintained regardless of the region (Fig. 32).

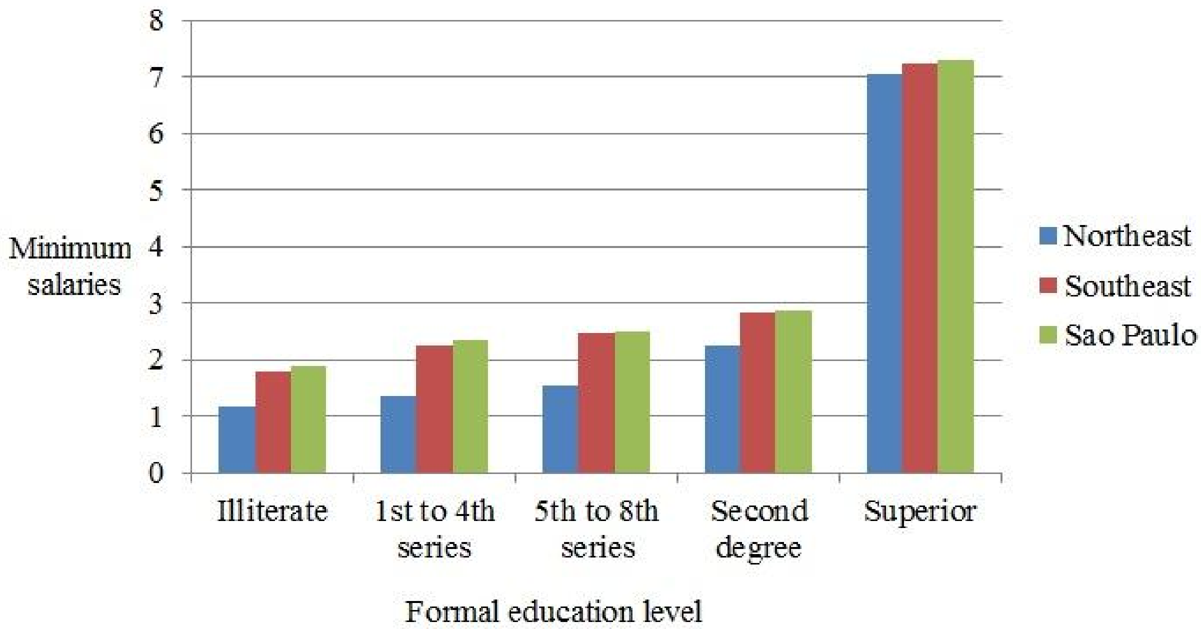

Fig. 32: Average remuneration (in minimum salaries) of the sugarcane workers by formal education level. Brazil, by region, 2006
Source: Adapted from data from RAIS, 2006, apud Liboni, 2009

A study from Moraes (2009) tried to identify and quantify the determinants of the income of the employees working in the production of sugarcane in different regions of Brazil through an income equation. According to this study, in 2006 workers with up to 9 years of schooling had an increase of 2.1% for each additional year of study of the estimated income. For those with 9 or more years of education, this increased to 9.6%.

Formal skill formation as a capacity influencing feature

According to Moraes (2010), in 2008 about 120,000 sugarcane workers were illiterate, representing 23.8% of the total. Workers with the lowest levels of education have fewer chances to stay in the sector because the sugarcane harvesters with higher levels of education have more possibilities to take part of the qualification programs offered by various stakeholders. Their ability to be absorbed into other sectors of the economy (e.g. the industrial or services sectors) will also be limited. According to Moraes et al. (2009), the average schooling years in 2007 were 7.7 for the employees of the alcohol sector and only 4.2 for sugarcane workers.

The fast expansion of mechanized harvesting is linked to a rapid increase of the average schooling years in the sector. The average number of schooling years in the sugarcane workforce in 2002 and in 2007 increased by 52% while for the alcohol sector this indicator increased only 5.1% (Moraes et al., 2011).

5.5 Demographics

According to the stakeholders interviewed, the specific characteristics of each worker could impact either positively or negatively their ability to stay in the sector after harvest mechanization. These potential influencing factors will be analyzed under the next subsections.

5.5.1 Age group

The average age of the sugarcane worker is lower than that of employees occupied in industrial branches (Moraes et al., 2009). According to Moraes et al. (2009), in 2007 the average age of Brazilian sugarcane workers in Brazil was 33.9 and in the ethanol sector this indicator was 35.8.

When taking into consideration the distribution of the formal sugarcane workers based on their age group, IBGE documented that in 2006 the largest proportion (45.7%) was between 25 and 39 years old, followed by the workers between 40 and 49 (21.6%) and 18 to 24 years old (18.9%). The proportion of workers from 50 to 64 is 12.6%. The proportion of workers younger than17 years old was 0.3% (Liboni, 2009). The Figure 33 below shows that this distribution closely corresponds to the age structure of the entire agricultural sector.

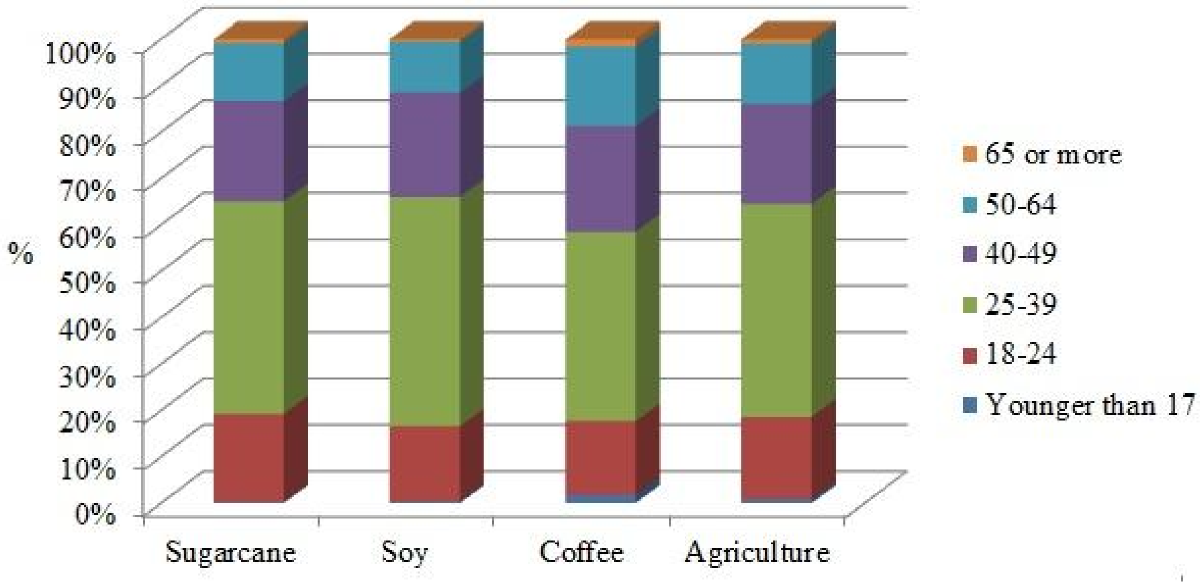

Fig. 33: Age group distribution of workers of sugarcane and other selected crops. Brazil, 2006
Source: Adapted from data from RAIS, 2006, apud Liboni, 2009

According to Alves (2006), during the 1990s employers of sugarcane workers adopted the strategy of hiring younger workers in order to achieve higher levels of work productivity. Notwithstanding this trend, the evolution of the average age of the sugarcane workers showed an increase because it has been influenced by the reduction of the child labor consequence of the increased auditing and surveillance of the sector (Fig. 34).

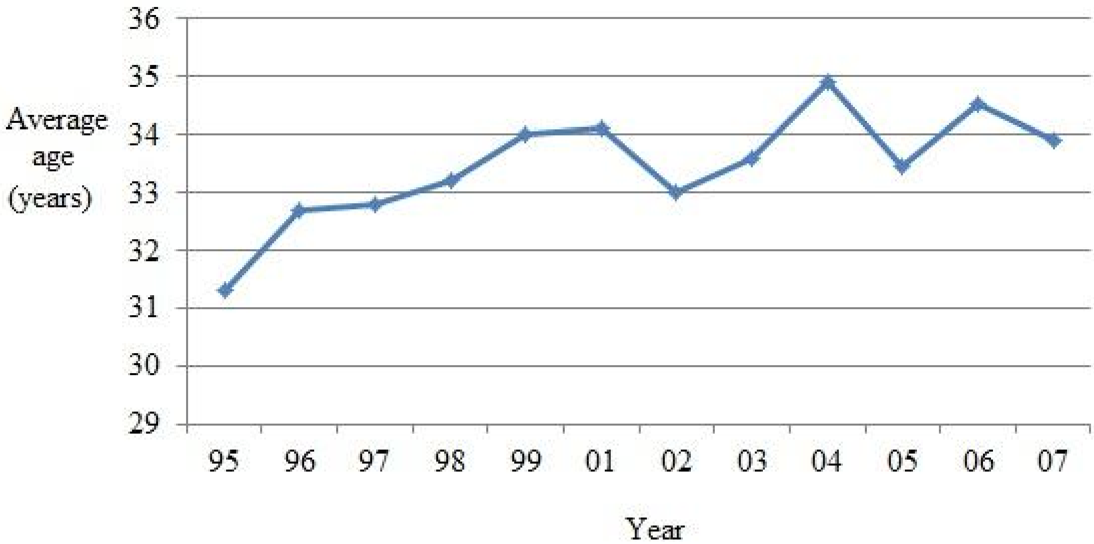

Fig. 34: Evolution of the average age of the sugarcane workers. Brazil, 1995-2007
Source: Adapted from data from PNAD, 1995-2007, apud Oliveira, 2009

Child labor[15] in Brazil, as in most developing countries, has been an existing phenomenon historically. IPEA (2010) documented that Brazil has made significant progress in reducing it over the past years. IPEA (2010) noted that the number of working children aged 5 to 14 decreased from 14% in 1990 (ca. 5 million children) to 5.1% (1.7 million). According to Langellier (2010), Brazil is ahead of the International Labor Organization target to reduce child labor by between a third and a half within 25 years. Brazil holds fourth place for best performance in Latin America, behind Colombia and Costa Rica.

Despite the general improvement in the socioeconomic conditions of the population, the most relevant factor for these advancements has been the creation of policies aimed at eradicating child labor. These policies account for more than 80% of the decline of this indicator (IPEA, 2010). Langellier (2010) noted the effectiveness of the program Family Scholarship (*Bolsa Familia*), created in 2003, by which a monthly allowance is provided by the state to deprived families on the condition that their children attend school and are up to date with their vaccinations.

According to IPEA (2010), regardless of the progress achieved, the share of children working is still high in the most vulnerable socioeconomic groups (e.g. rural areas, Northeast region, poor households, black-skin population). In these groups, the share of children working is up to 20%, 4 times higher than the country's average. Langellier (2010) noted that in the North and Northeast region more than 4 out of 10 children work in agriculture.

Child labor in sugarcane is limited compared to other agricultural activities and has historically reduced its levels (Smeets et al., 2008). In Pernambuco during the early 1990s, around one fourth of the sugarcane harvesters were between the ages of 7 and 17 (BNDES/CGEE et al., 2008). In 1992 the percentage of children working in sugarcane production in Brazil was ca. 14.7% of the total of temporary rural workers and 10.8% of the total urban workers. In 2005 these statistics were 3.3% of the total of temporary rural workers and 0.5% of the total urban workers. Child labor was inexistent among permanent employees (Basaldi, 2007).

The average sugarcane worker age has followed the agricultural trend (Fig. 35).

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15 In Brazil children between the ages of 14 and 16 can be hired as apprentices under the CLT (*Consolidação das Leis do Trabalho*) (Sect. 6.2). Children must have permission from their parents or guardians, attend school, work part time, and not work under hazardous conditions. Annex I of the CLT describes the locations and services considered hazardous or unhealthy for workers under 18 years of age. Planting, harvesting, processing, and manufacture of sugarcane are in this list (item 81) (Government of Brazil, 2012).

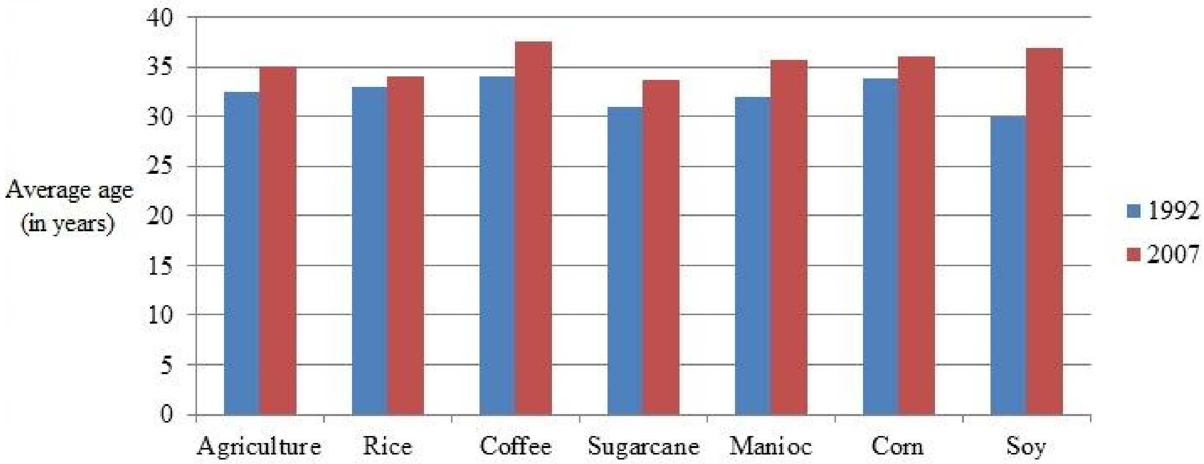

Fig. 35: Evolution of the average age of workers of sugarcane and other selected crops. Brazil, 1992 and 2007
Source: Adapted from data from PNAD, 1992 and 2007, apud Oliveira, 2009

The average age of the sugarcane workers in Brazil does not show major variations among the producing regions (Moraes, 2007).

5.5.2 Gender

According to the Summary of Social Indicators in 2009 the male workforce was 53.2% of the total number of formal jobs in Brazil while female participation was 48.8% (IBGE, 2011). Agriculture is an important source of employment for women in Brazil. Alttiman & Costa reported in 2009 that most women are concentrated in four occupational categories that together encompass approximately 70% of the total workforce: services (30.7%), agriculture (15%), administrative services (11.8%) and commerce (11.8%). According to Fredo (2011), women have a disadvantage to reach essential social resources. Nevertheless, female participation in the labor market has increased in order to complement the family income (Fredo, 2011).

Since the 1990s, women have been excluded from several stages of sugarcane production (Padrao, 1997; Silva, 2011; da Costa, pers. comm., 2010). This trend can also be observed in other cultures as well (Fig. 36).

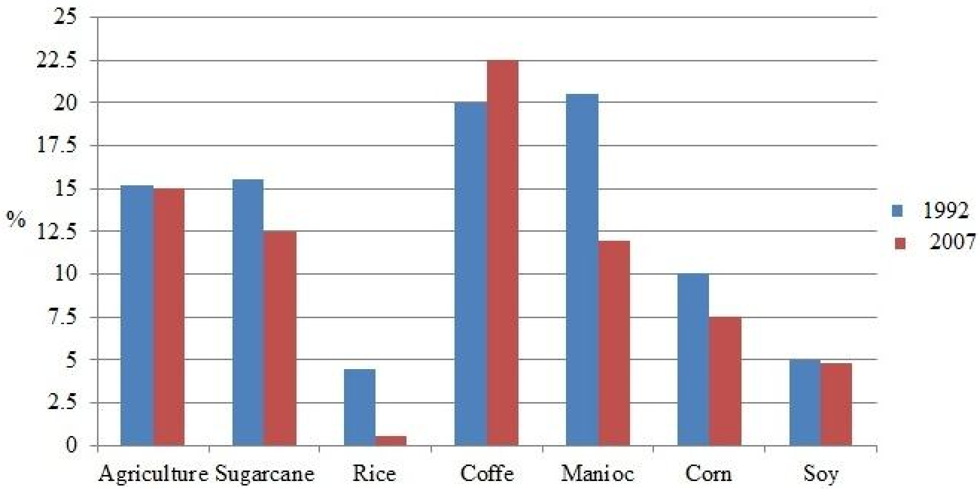

Fig. 36: Evolution of the share of women among the workers of sugarcane and other selected crops, Brazil, 1992-2007
Source: Adapted from data from PNAD, 1992 and 2007, apud Oliveira, 2009

Fig. 36 above shows that for the entire agricultural sector, the share of women has shown little variations. On the other hand, the trend of reducing the percentage of women was observed for the cultures of sugarcane, rice, manioc, corn and in less extent soy. Coffee is the only culture in which the female participation had increased.

The reduction of female labor in sugarcane agriculture has been attributed to diverse causes including: lower productivity of women in comparison to men (due to less physical strength), sharp increases in the average productivity demands (da Costa, pers. comm., 2010; Padrao, 1997), the costs for having extra facilities for female personnel (Silva, 2011), and to avoid the costs associated with pregnancy (Padrao, 1997). Some of the dismissed female sugarcane harvesters currently work as maids and cooks in the urban areas (da Costa, pers. comm., 2010).

A high proportion of male workers can be observed in most of the agricultural activities associated with the sugarcane production (Cardoso, 2010). The sexual division of the work designates men to take on the following roles: harvester, supervisor, driver, intermediary for the supply of temporary workers (*turmeiros)*, driver of machines, tractors, trucks, fire team, fire supervisors (Silva, 2011). According to Fredo (2011), gender has been an element of occupational segregation restricting women to activities with low mobility in terms of professional promotion and high instability. Silva (2011) suggested that women are being designated for specific activities in the sugarcane fields such as planting, *bituca*[16], and stone removal. Stone removal is carried out before the mechanized harvest. It is a dangerous

[16] The *Bituqueiras* are women in charge of picking up the *bitucas* (small pieces of sugarcane leftovers) left on the field after the manual sugarcane harvest and the crane collection.

activity because the workers can encounter poisonous animals under the rocks such as cobras and scorpions. These activities are tiring and demanding because they require bending during most of the work shift. In addition this kind of job is usually unappreciated (Silva, 2011). Usually, these activities have salaries lower than those dominated by male workers and are more vulnerable to having their labor rights violated (Silva, 2011). Some women carrying out these activities are not hired for the whole harvest by the sugarcane mill, but they are hired in groups to carry out activities depending on the cycles of the cultures. This kind of work called *volante*, involves rotation in cultures with short harvesting periods such as tomato and mango (only three harvest months per year) and onion (four months per year) (Silva, 2011).

Reductions in the share of women in the sugarcane workforce can be observed in the Brazilian macro-regions (Fig. 37). According to Moraes (2009), even when there is a predominance of men working in sugarcane in all regions, the Center-South has a larger proportion of women compared to the North–Northeast which could be due to the mechanization of agricultural activities. Oliveira (2009) noted that in 2007 the percentage of women in the sugarcane workforce in the Center-South and Sao Paulo state was still higher than the average for the entire agricultural sector.

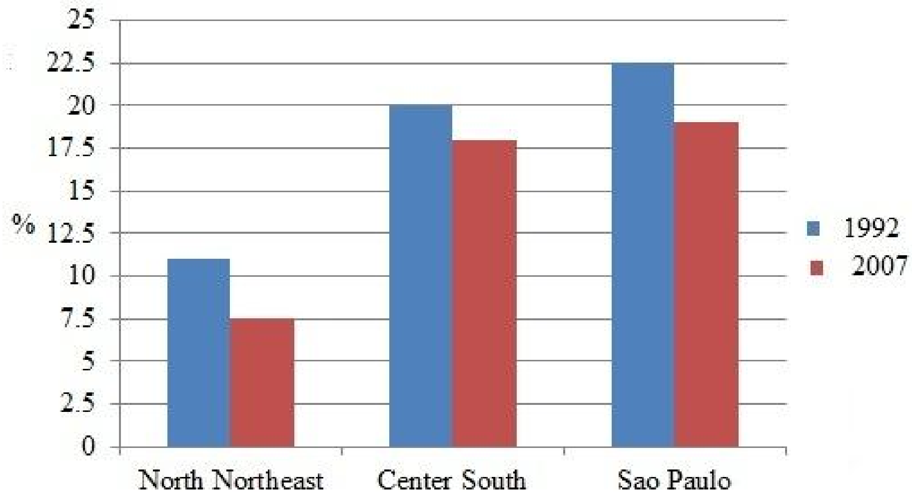

Fig. 37: Evolution of the share of women among sugarcane workers. Brazil, by region, 1992 and 2007
Source: Adapted from data from PNAD, 1992 and 2007, apud Oliveira, 2009

The remuneration equation developed by Moraes (2009) reported that in 2006 women earned 20.7% less than men. Moraes (2009) explained this income difference with the productivity levels (Sect. 5.6).

5.5.3 Other aspects

According to Silva (2011), since the end of the 1950s the black and mestizo population coming from the Northeast of the country carried out the agricultural work in the sugarcane fields of the Center-South region by means of permanent or temporary migration.

According to IBGE (2011), Brazilian illiteracy rates, functional illiteracy and schooling years vary among the population depending on the color of their skin. Black skin and mestizo groups show lower levels (in terms of formal education) compared to the white population. IBGE (2011) suggested in its Summary of Social Indicators that in Brazil the hourly income of people with black skin and mestizos is ca. 40% lower than that of the white population. IBGE (2011) suggested that one of the drivers for this trend is the countries' power structure. Most employers are white while mestizos and the persons with black skin represented the largest share of informal employees and domestic employees (IBGE, 2011).

Nevertheless, in the agricultural sector, the color of the skin seems not to be a significant variable determining the average income of the workers. Hoffmann & Ney (2004) developed an income equation to identify and quantify the determinants of the income of the employees working in the agricultural sector in Brazil. According to this study, based on data from 1992-2002, the factor marginal contribution of race for the square sum of the regression of the income adjusted equations was 0.6. This value is low compared to others variables such as region (6.9) and occupational category (9.2). Other factors analyzed were age (3.7), schooling (5.7), gender (1.3), and hours worked per week (8.55).

Demographics as a capacity influencing feature

Personal interviews with representatives from industry and employers suggested that the mechanization of the sugarcane harvesting operation is an opportunity for women to make a "come back" to the sector. The agricultural manager of one sugarcane mill[17] in the Center-West of Brazil noted that they had encountered severe difficulties in finding qualified workers for the facilities and that would not be a problem for them to employ women if they met the required qualifications.

A representative from industry noted that, based on the female stereotypes of being more careful and detail oriented, women could be an appealing option to operate and take care of the machinery. Both of the interviewees agreed that mechanization could also increase the average age of workers in the sector, because the activities would be less physically demanding.

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[17] *Usina São Francisco*, in Quirinopolis, Goias

Currently, the percentage of women in the mechanized harvest is still very low. Fredo et al. (2008) suggested that the percentage of women operating tractors in Sao Paulo state was only 0.3% in 2007 (Table 18).

Table 18: Occupations' distribution by gender and age group. Sao Paulo, 2007

Occupation	Gender (%)		Age group (%)						
	Male	Female	Up to 17	18-24	25-29	30-39	40-49	50-64	Above 65
Sugarcane harvesters	87.6	12.4	0.3	36.3	20.5	25.1	12.8	4.8	0.2
Tractor driver and operator	99.7	0.3	0.1	22.2	20.8	32.9	18.8	5.2	0
Supervisors	96.5	3.5	0.4	19.9	19.7	33.5	18.9	7.3	0.3

Source: Cardoso, 2010, CAGED, MTE, apud Fredo et al. 2008

Table 18 shows that there are differences on the distribution of the workers based on the age group in Sao Paulo state. When taking into consideration the category of tractor drivers and operators, the largest proportion (32.9%) was between 30 and 39 years old while the largest proportion (36.3%) was between 18 and 24 years old for manual harvesters.

According to Fredo (2011), it seems reasonable to expect that young people (from 18 to 24 years old) will not face problems in being reabsorbed into the sector. On the other hand, Fredo (2011) also noted that groups of workers 40 years or older will encounter difficulties being reabsorbed into the sugarcane or any other industry.

5.6 Productivity

According to Basaldi (2007), the factor contributing to the success of the agro-industry in Brazil are the productivity increases in all the production factors (land, capital and labor). Some of the agricultural productivity increases are related to the yields of sugarcane and the advancement of harvesting mechanization. In addition, there have also been important productivity increases in the manual sugarcane harvesting operation (Fig. 38).

During the last decades, the average productivity of the manual sugarcane harvester measured in tonnes/days per worker has been increasing. Basaldi (2007) documented that in 1969 the average amount of sugarcane harvested per day was 3 tonnes. In the 1980s the average productivity demanded by some sugarcane mills rose to 5-9 tonnes per day, and became 8-9 in 1990 (Basaldi, 2007). According to Silva (2008), during the first decade of the 2000s, some sugarcane mills in Sao Paulo raised the amount to 10 tonnes per day or in extreme cases to 12 or 15 tonnes per day. Figure 38 shows the evolution of the average productivity of sugarcane harvesters in Sao Paulo during the last decade.

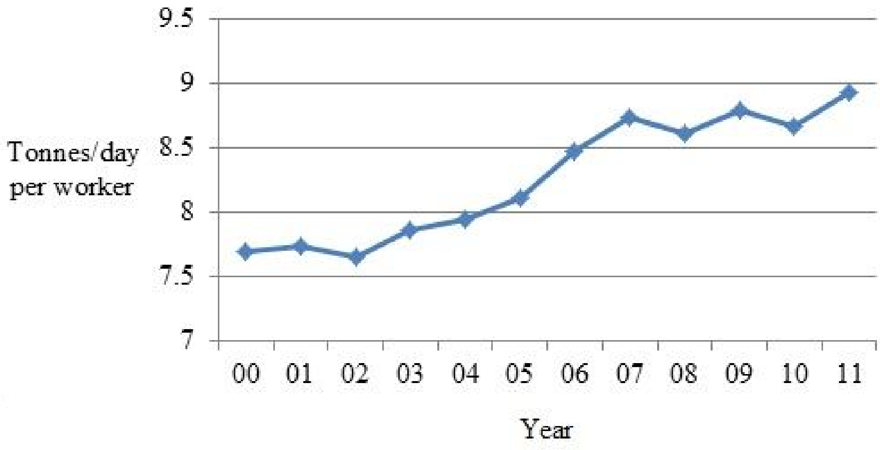

Fig. 38: Evolution of the average productivity of sugarcane manual harvesters. Sao Paulo, 2000-2011
Source: IEA[2]/CATI, 2012

According to Alves (2007), the productivity increase is associated with the economic incentive (production-based payment) and the use of specific criteria for the selection of workers. Silva (2008) suggested that this trend was also driven by the escalation of the minimum productivity requirements imposed by the sugarcane mills. There are regional differences in the productivity evolution of the manual sugarcane harvesters (Fig. 39).

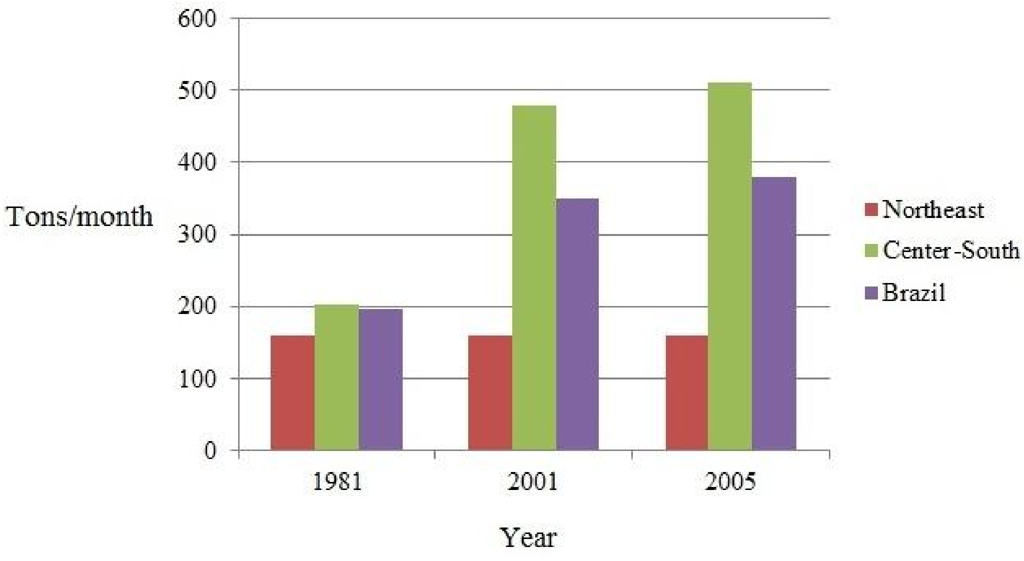

Fig. 39: Evolution of the average productivity (in tonnes/month) of manual sugarcane harvesters. Brazil, 1981, 2001 and 2005
Source: adapted from Moraes, 2007

Figure 39 shows that the average productivity of the manual sugarcane harvesters in the Northeast region did not have a significant increase in comparison to other producing regions. These differences in productivity are not exclusive to the agricultural occupations but they were observed in the entire agro-industry.

According to IBGE in 2008, the production of sugarcane in the North and Northeast region accounted for 11.7% of the country's total production while the share of jobs was 43.6%. The same year, Sao Paulo was responsible for 59.8% of all Brazilian sugarcane production with only 35.7% of the workers of the sector (IBGE, 2008).

The wages paid to sugarcane workers is based on the meters of sugarcane harvested, converted to tonnes and the varieties of sugarcane or the saccharide level of the sugarcane are identified[18] (Parra, 2009). This payment method has a legal base and is detailed in art.457 of the labor laws (Sect. 6.2). Other agricultural activities adopting the production based paying method are cotton, coffee, orange, lemon and tangerine (IEA^2/CATI, 2012; Oliveira, 2009).

The payment received by the harvesters varies from producer to producer. The average in 2011 was ca. R$ 3.7 per tonne in Brazil (Silva, pers. comm., 2011). For the same year it was R$ 4.4 in Sao Paulo according to IEA^2/CATI (2012).

Remuneration depends on variables such as the sugarcane age and the degree of difficulty in cutting it. A case study illustrating these differences was documented by Reporter Brasil. Reporter Brasil (2010) documented that in a sugarcane mill in 2009 the plant and the workers' union had a collective bargaining agreement stipulating that the minimum that each harvester would receive was R$18.8 per day[19]. The sugarcane that was cut after 18 months had a value of R$3.3 per tonne. The other cuts were R$3.2. A 10% supplement over the standard price was paid for the harvest of sugarcane that was cut “laid” and 25% extra was paid when the sugarcane was “rolled”. This percentage appears to be high compared to other employers. An agricultural manager from a sugarcane mill in Sao Paulo revealed to the author in a personal interview that his mill did not have a standard price for the sugarcane with different difficulty degrees, but provisory prices applied with an increase that varied from 6% to 8%. Some employers do not even consider these differences in difficulty degrees when calculating the payment (Aguiar, pers. comm., 2010).

The mechanization of the harvesting operation is expected to generate jobs with better remuneration. For instance, a sugarcane harvester in the region of Riberao Preto (in 2010) suggested in a personal interview that when he was a manual sugarcane harvester he earned on average R$1,800 per month. After being qualified to operate a mechanical sugarcane harvester, he earned on average R$2,800 per month. The rural worker highlighted the difference in working conditions of both activities.

According PNAD, in Brazil in 2006 the average remuneration of the sugarcane workers appeared to be higher than that of other agricultural workers (Fig. 40). Figure 40 shows that

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[18] This conversion is carried out through a sampling method using a truck which after being filled with sugarcane from three points is weighted at the mill and from this weight the value of the ton is converted in the value of the meter (Alves, 2009).

[19] According to the art. 8 from the CLT the minimum monthly salary has to be guaranteed, regardless the payment to the worker is based on their production.

the average soy worker received a higher wage than sugarcane workers. This could be explained by the high degree of mechanization of soy culture.

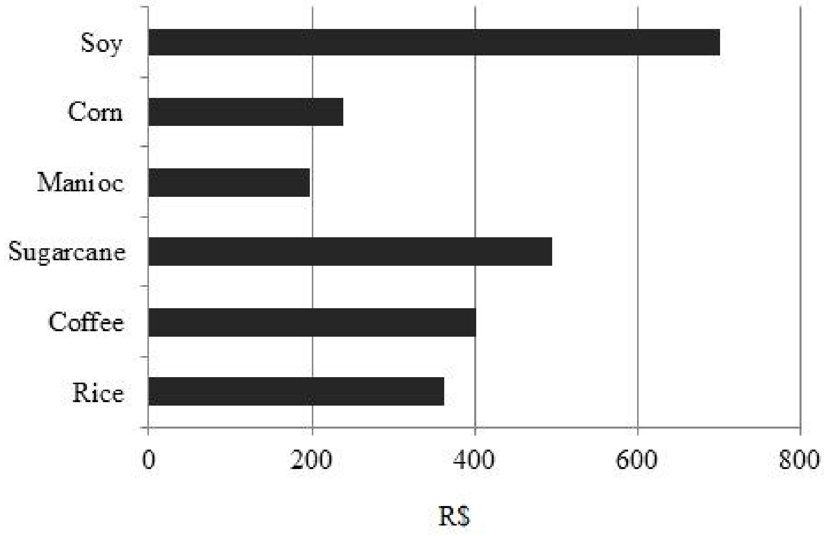

Fig. 40: Average remuneration (in Brazilian Reais) of the workers of sugarcane and other selected crops. Brazil, 2006
Source: Hoffmann & Oliveira, 2008b

The data set from IEA[2]/CATI reveals that the remuneration of sugarcane harvest in Sao Paulo for the same year (2006) was relatively low compared to the other agricultural products such as cotton, coffee, orange, and lemon, even when sugarcane demands a grand physical effort from the worker (Oliveira, 2009) (Fig. 41).

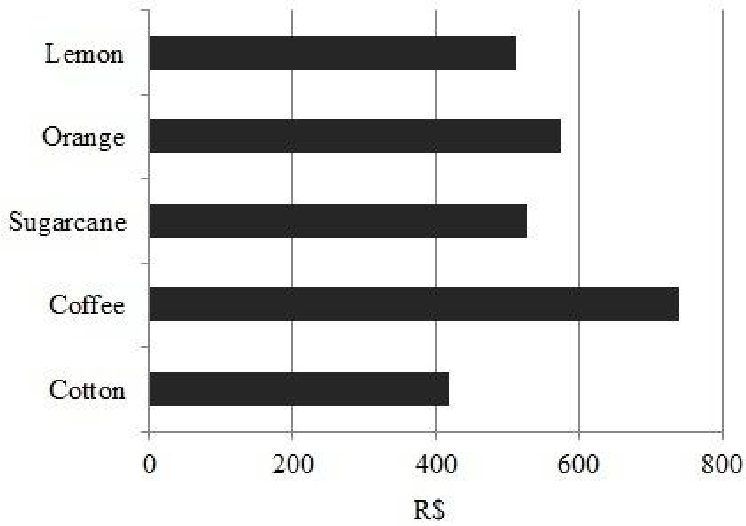

Fig. 41: Average remuneration (in Brazilian Reais) of the workers of sugarcane and other selected crops. Sao Paulo, 2006
Source: IEA[2]/CATI, 2006

In 2011 in Sao Paulo the average income per sugarcane worker was R$ 796 while it was higher for workers of cotton (R$ 814), coffee (R$1,500), orange (R$956), and lemon (R$ 908) (IEA[2]/CATI, 2012).

Various authors have pointed out that the average remuneration per tonne of sugarcane harvested did not evolve with the same intensity as the productivity of the sugarcane harvesters. Figure 42 illustrates the trends of both: the average productivity of the sugarcane harvesters and the average payment per tonne in Sao Paulo.

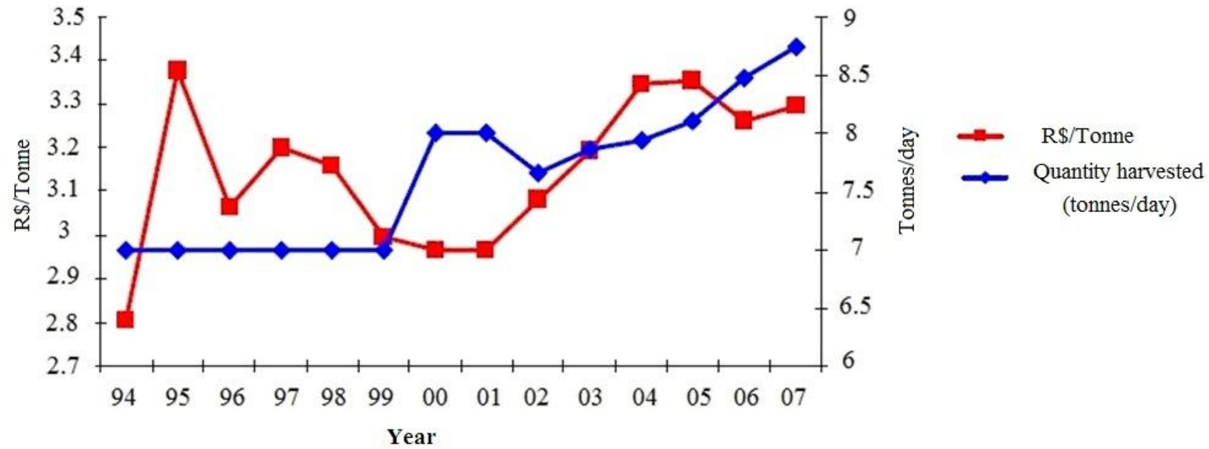

Fig. 42: Evolution of the average payment* (in R$/tonne) and the average amount of sugarcane harvested per day. Sao Paulo, 1994-2007
Source: Hoffman & Oliveira, 2008b
Note*: In R$ from 2007 using the Consumer National Price Index (INPC) as deflator

According to Hoffman & Oliveira (2008b), it seems reasonable to acknowledge that the increases in productivity have contributed to the increase in average remuneration of sugarcane workers over time (Fig. 43) but not as the only influencing factor. Hoffman & Oliveira (2008b) suggested that the growth of the real value of the minimum salary had also promoted this trend.

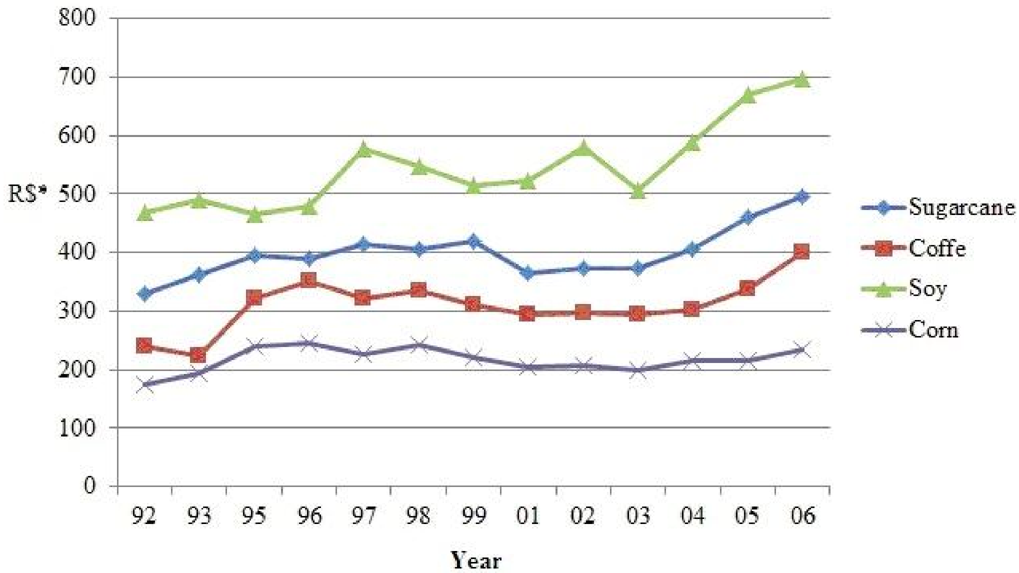

Fig. 43: Evolution of the average income* of the workers of sugarcane and other selected crops. Brazil, 1992-2006
Source: Hoffmann & Oliveira, 2008
Note*: In R$ from 2007, using the Consumer National Price Index (INPC) as deflator

According to Oliveira (2009), the minimum salary is an important institutional variable in determining the agricultural wages in Brazil. Figure 44 shows a dispersion diagram of the minimum salary and the remuneration of the sugarcane workers.

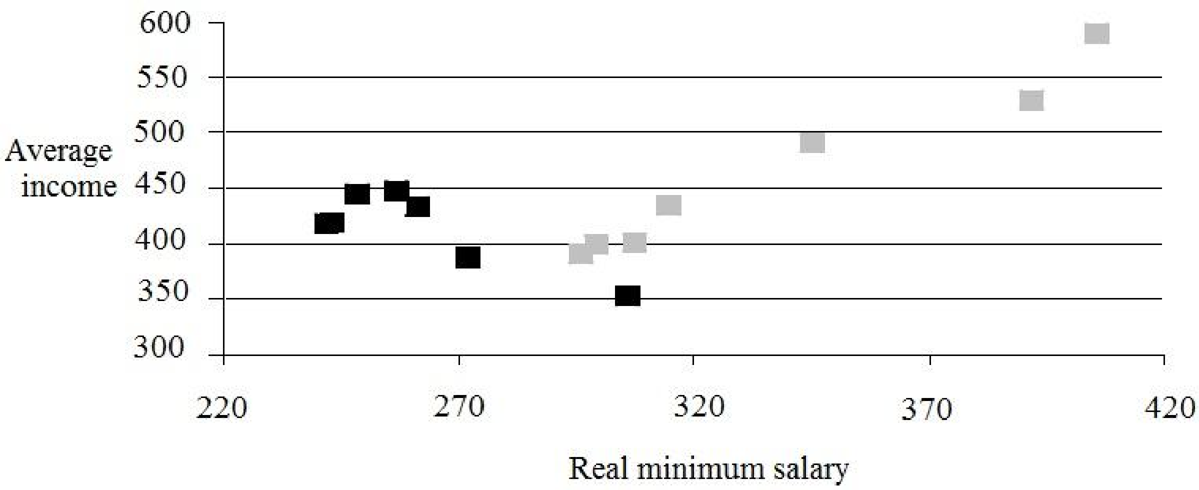

Fig. 44: Dispersion diagram of the real minimum salary and average real remuneration of the sugarcane workers. Brazil, 1992-2007
Source: Oliveira, 2009
Note*: in R$/month, in current values
Note**: The black dots illustrate the values from the period 1992-2000 and the grey dots of the period 2001-2007
r = 0.69 (1992-2007)
r = 0.98 (2001-2007)

According to the r values obtained from the Figure 44, it can be observed that the degree of correlation from 2001 to 2006 is higher than that observed in the total time series.

Smeets et al. (2008) documented that, on average, a sugarcane harvester earns 1.8 times the minimum wage during 8 months (the maximum harvesting season). This amount would have equalled 1.2 times the minimum wage after reallocating it over the whole year studied.

Alves (2008) examined the degree of correlation of monthly income of the sugarcane harvesters with the minimum salary in various years from 1986 to 2005 (Table 19).

Table 19: Evolution of the average income (in minimum salaries) of sugarcane harvesters. Sao Paulo, 1986, 1989, 1995, 2005 and 2007

Year	Daily income	Monthly income	Minimum Salary	Value in minimum salaries
1986				2.5
1989	5.6	168.6	81.4	2
1995	6.2	186	100	1.8
2005	12.6	377.4	300	1.3
2007	12.7	460	380	1.2

Source: Adapted from Alves, 2008
Note*: R$ in current values

Table 19 reveals that in Sao Paulo there was a decline in nominal wages for sugarcane workers when measured in minimum salaries. According to Alves (2008), this trend was not exclusive for Sao Paulo. In Goias, for instance, the value of the monthly income of the sugarcane harvesters in terms of minimum salaries went from 2 in 1989 to 1.3 in 2007 while in Pernanbuco it went from 1.2 in 1989 to 1 in 2005 (Alves, 2008).

Nevertheless, Hoffman & Oliveira (2008) noted that it is not correct to interpret this as an evidence of decline of the real value of the remuneration due to the significant increase of the real value of the minimum salaries, which increased more than 60% between 1995 and 2006 (Hoffman & Oliveira, 2008). According to Basaldi (2007), the real salary gains from 1992-2005 were 17.6% for the permanent workers with rural residence, 37.2% for the temporary workers with rural residence, 34.5% among the permanent sugarcane workers with urban residence, and 47.6% for the temporary workers with urban residence.

The production payment method is a controversial topic in spite of its legal background. Even the unions' position is not homogeneous. On the one hand, some workers are in favor of keeping such a scheme because they assume that they would be able to generate more income (Aguiar, pers. comm., 2010). Furthermore, the UNICA (2011) considers that this payment scheme contributes to adequate payment for the harvesters. On the other hand, this system has been questioned because of its assumed connection with deaths due to extreme workload motivated by higher wages (Pastoral do Migrante, 2005; Novaes 2007; Alves, 2006; Rumin et al., 2008). From 2004 to 2010, 23 workers' deaths were reported during the sugarcane harvest (Silva, pers. comm., 2010).

Moraes & Ferro published in 2008 a study about mortality and retirement indicators among the sugarcane harvesters. This study showed that in 2005, of the total agricultural workers (excluding sugarcane) in Brazil, 0.134% died. From this total, 0.007% were related to accidents in the work location or during the transportation to their work localities. For the sugarcane workers, these figures were 0.105% and 0.004% respectively. When analyzing deaths by age group it was found that for the sugarcane, as for other agricultural activities the major occurrence was from 50 to 64 years old. In Sao Paulo from the same year, from the entire agriculture (excluding sugarcane) 0.125% of the workers died from which 0.007% cases were related to accidents in the work location or during the transportation to their work localities. For the sugarcane workers these figures accounted for 0.089% and 0.004% respectively. This study also noted that even when media reports have suggested that sugarcane workers retire early because of injury, the age group showing the greatest number of retirees in the sugarcane sector was from 50-64 (72.4% of the total) which coincides with farming as a whole (63.9% of the total), concluding that the sugarcane sector reflects the situation of the agricultural activities.

The mechanization of sugarcane harvesting is expected to have significant changes in the pattern of work-related accidents. Scopinho (1999) carried out a study analyzing the consequences of mechanization on the health of workers. This study concluded that there is evidence of a decrease in their frequency and increase in severity. This last point would draw the attention towards the need for specialized training in order to avoid accidents operating or maintaining the equipment.

Productivity as a capacity influencing feature

According to the employers, sugarcane harvesters and workers' union leaders interviewed the performance of the sugarcane workers highly determine their perspectives for remaining in the sector. This seems reasonable given the production demands established by the employers and the temporary nature of the work contracts. According to the stakeholders interviewed, other aspects such as health status and attitude are determinant for the further hiring of workers in consecutive harvests. As mechanization expands, it could be expected that the most productive and healthy workers will remain in the sector increasing their opportunities for having access to qualification programs.

Sugarcane harvesters acknowledged in personal interviews that given the physical demand of the harvest activities, it was difficult for them to look for qualification opportunities in their spare time. They noted that the best option for them was to do their qualification courses as part of their daily job activities. This scheme has been adopted for instance by the program RenovAção offered by the industry representatives (Chapter 7).

5.7 Intermediate conclusions: capacity influencing features

The analysis of the capacity influencing features revealed that: (i) key socio-economic indicators of the rural workforce vary in a regional basis, with a sharp substandard trend in the workers from the North and Northeast, (ii) these regions, which have shown a general economic stagnation, are the points of origin of the migrant workers, (iii) general low levels of formal education will hinder the employment perspectives of these workers in (almost) any sector of the economy, (iv) the participation of women in the sector has decreased gradually over the years. In order to foster their permanence in the agro-industry, their participation in qualification programs could be promoted, (v) workers with high productivity are expected to remain in the sector, ensuring the productivity of the entire agro-industry, and (vi) an organized syndical movement could be part of the implementation of strategies to solve the complex problematic and influence the dynamics of the labor market developments.

Chapter 6

6. Labor market influencing features

Currently the Brazilian sugarcane agro-industry is undergoing a transition in which the manual harvesting operation is being replaced by a mechanized harvesting practice. Given the rapid adoption of the new technologies in the sugarcane fields, it is important to analyze the labor market trends in the context of the factors that are influencing these developments. Sect. 6.1 covers the national and international market trends that influence the expansion of the sector. Sect. 6.2 analyzes the labor and environmental legislation framework to which the sugarcane agro-industry is submitted. Sect. 6.3 revises the current agricultural trends with a focus in the increasing levels of mechanization and the reduction of workforce demand. Sect. 6.4 identifies the influencing features affecting the mechanization adoption rate. Sect. 6.5 details the Agro-environmental Zoning initiative, considering its importance for the geographical re-configuration of the workforce demand in short-medium term. Sect. 6.6 gives some conclusions about the analyses of the labor market influencing features.

6.1 National and international market developments

The national and international market developments of the two main products of sugarcane (ethanol and sugar) are expected to influence its production.

6.1.1 National developments

According to USDA (2011), the determinants influencing whether sugarcane is milled for sugar or for ethanol are: (i) the expected level of world sugar prices, and (ii) the price of ethanol in the Brazilian domestic market, which in turn depend on the domestic demand (which in turn would also be affected by the world prices of gasoline). Until 2008, that relationship favored ethanol over sugar (USDA, 2011). Ethanol is used in large scale as fuel in two ways: (i) as hydrated alcohol, commercialized via specific pumps in the fuel stations (feeding flex-fuel vehicles and vehicles exclusively using alcohol), and (ii) as anhydrous alcohol blended with gasoline by mandate (MDIC, 2012). According to EPE (2011), the total ethanol production in Brazil in 2010 increased 7.1% compared to the previous year (2009) resulting in 27.9 million m³ (Table 20).

Table 20: Ethanol production and consumption (in million m^3). Brazil, 2001-2010

Year	01	02	03	04	05	06	07	08	09	10
Production	11.5	12.6	14.5	14.6	16	17.7	22.55	27.2	26.1	28
Total consumption	11.6	12.5	11.9	13.3	14	13.4	17.3	22.8	24.3	25.7

Source: Adapted from EPE, 2011

Brazil is the world's second largest ethanol consumer behind the United States. In 2009 Brazil consumed 22.7 billion liters accounting for 31% of the total global ethanol consumption. According to ANP (2009), 80% of the total domestic demand of ethanol in Brazil is concentrated in the South and Southeast regions. In 2009, 96% of the ethanol in Brazil was used as fuel and the rest for industrial use (USDA, 2011).

According to EPE (2011), in 2010 ethanol contributed with 17.3% to the total Brazilian transportation matrix in energy terms (with 12,243 10^3 toe). The largest share was diesel oil with 48.6% followed by gasoline 25.2%. The remaining share was contributed by querosene (4.6%), oil fuel (1.4%) and others (2.8%). Regarding the terrestrial highway transportation matrix, ethanol accounted for 18.8% of the total energy consumption. The largest share was diesel oil (51%), followed by gasoline (27.4%) and the remaining 2.8% was contributed by natural gas (EPE, 2011).

The Law No. 8.723/93 pronounced that the Brazilian Government[20] is responsible for fixing the percentage of the blend of anhydrous alcohol with gasoline in a share from 18% to 25%. Before the publication of the Law No. 12.490/11, the minimum blending share of ethanol in Brazilian gasoline was 20% (MDIC, 2012). Figure 45 below shows the evolution of the gasoline, anhydrous and hydrated ethanol consumption.

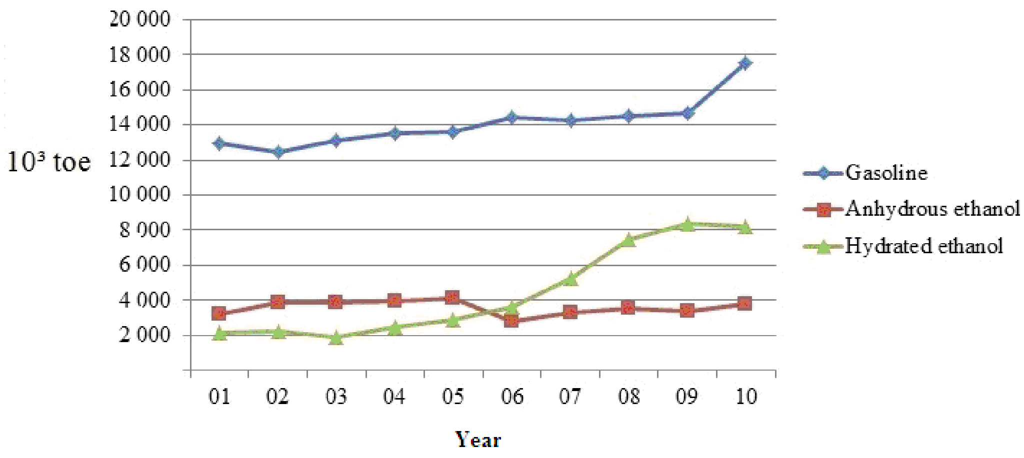

Fig. 45: Evolution of the gasoline, anhydrous, and hydrated ethanol consumption (in 10^3 toe). Brazil, 2001-2010
Source: EPE, 2011

According to the USDA Agricultural Projections, from 2012 to 2021, Brazilian ethanol production is projected to increase more than 90%. Its share of exports is also expected to augment (USDA, 2011a). These exports are expected to grow rapidly during the early years of the next decade but slow in the later years due to increases in its domestic demand.

[20] The entity responsible for defining the share of anhrydrous alcohol in the gasoline is the Interministerial Council for Sugar and Alcohol (*Conselho Interministerial do Açúcar e do Álcool* - CIMA).

6.1.2 International developments

In 2009 biofuels provided 53.7 Mtoe, equivalent to ca. 3% of road transport fuels worldwide (2% of all transport fuels). The sector has grown 26% from 2005 to 2009 (OECD/IEA, 2011). In 2010 the global biofuel production grew by 13.8% accounting for 0.5% of the primary energy consumed. Ethanol accounts for ca. 75% of the global production of biofuels (IEA, 2011). The main production and consumption centres for ethanol are the U.S.A. and Brazil, while the European Union mostly produces and consumes biodiesel. In 2010 together, the U.S.A. and Brazil produced ca. 86% of the world's fuel (RFA, 2011). The Table 21 shows the major world ethanol producers.

Table 21: World fuel ethanol production (in million liters)

Country	2007	2008	2009	2010
United States	24,599.8	34,068.7	40,125.4	50,081
Brazil	18,999.7	24,499.9	24,900	26,200.8
European Union	2,158.8	2,777	3,935	4,455
China	1,839.7	1,899.9	2,050	2,050
Canada	799.9	899.8	1100	1350

Source: RFA, 2011

Currently, biofuel trade plays a limited but increasingly important role (OECD/IEA, 2011). Global ethanol trade augmented from ca. 550 million liters in the beginning of the 1990s to 6.4 billion liters in 2010. According to the USDA (2011), the world ethanol trade was estimated at 10% of the world’s levels of consumption in 2009. Even when Brazil plays an important role in the global ethanol trade, it exports only 13% of its total production (USDA, 2011). According to MCID (2012), in 2010 Brazil accounted for 30% of the global ethanol trade exporting 1.9 billion liters, a volume 42.2% lower than in 2009. In 2011 it exported 1.96 billion liters of alcohol, a volume 3.4% higher than that of 2010. Brazilian exports are supplied to more than 80 countries in regions such as: U.S.A., Japan, Jamaica, Nigeria, South Korea, Switzerland, Netherlands, Costa Rica, El Salvador and Mexico (MDIC, 2012a). U.S.A. is a key importer of Brazilian ethanol (accounting for ca. 664 million liters imported directly in 2011). Brazil also exported to Central American and Caribbean countries hydrated alcohol to be re-processed (dehydrated and transformed in anhydrous alcohol) and be then re-exported to the U.S.A. under the Caribbean Basin Initiative agreement (CBI)[21]. This procedure enabled the CBI countries to avoid the two duties that were imposed at that time by

[21] Since 1989, countries in Central America and the Caribbean have duty-free access to the U.S.A. for ethanol from regional feedstock. For ethanol derived from non-regional feedstock, a quota has been limited by the CBI quota equaling to 7% of the total ethanol consumed in the U.S.A. (USTR, 2012).

the U.S.A. on ethanol imports: a 2.5% tariff plus and an additional US$0.1427 per liter (US$0.54 per gallon). These tariffs were in place until the end of 2011.

From 2002 to 2009 Brazilian ethanol exports to Costa Rica, El Salvador, Jamaica and Trinidad and Tobago summed up 52% of its total exports (USDA, 2011). The Table 22 shows some key destination of the Brazilian exports of ethanol.

Table 22: Destination countries for the Brazilian exports and volume evolution from 2009 to 2011

Destination	2009	2010	2011
U.S.A.	272,193	313,394	663,925
South Korea	313,714	375,309	300,045
Japan	279,961	261,672	280,873
Jamaíca	437,657	138,622	137,589
Trinidad and Tobago	139,951	6,636	135,881
Switzerland	58,765	52,158	79,677
Nigeria	115,766	80,123	73,603
El Salvador	71,101	0	50,083
Netherlands	678,466	238,988	45,504

Source: MDIC, 2012a

In 2010, ca. 65% of the Brazilian ethanol exports corresponded to Sao Paulo (Fig. 46).

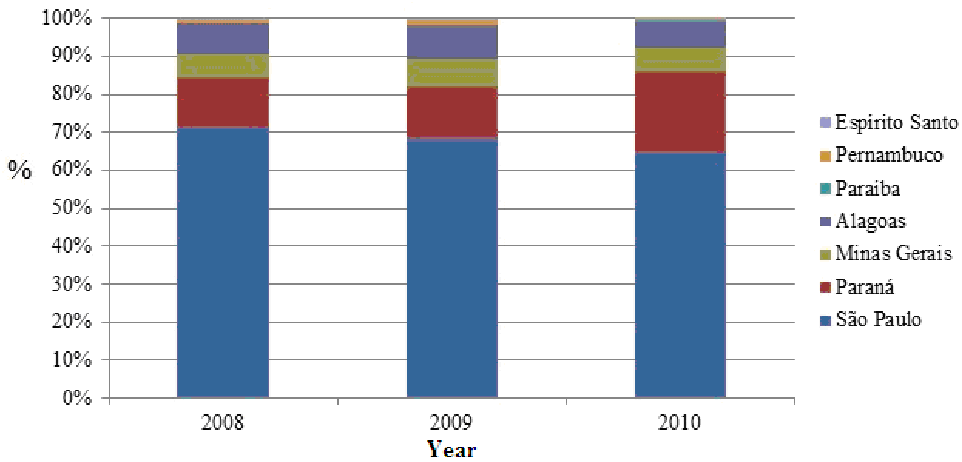

Fig. 46: Evolution of the Brazilian ethanol exports by federal entity from 2008 to 2010
Source: MDIC, 2012b

Until 2008 Brazil was the world's largest ethanol supplier accounting for more than 62% of the global export market each year. In 2008, the U.S.A. imported record amounts of ethanol accounting for 32% of the total Brazilian exports value-wise. According to the USDA (2012), by that period the U.S.A. demand was boosted by the Energy Policy Act of 2005, which mandated the use of ethanol in transportation and the elimination of methyl tertiary butyl ether (MTBE) as an additive in gasoline blending in important markets such as California.

After 2009, U.S.A. became the world largest ethanol exporter. The Brazilian exports to CBI countries fell to less than 8% in 2010. In 2011 Brazil imported 1.13 billion liters of alcohol, volume 1405% higher than that of 2010, with 1.1 billion liters imported directly from U.S.A., a massive amount compared to the 29.5 million liters imported from 1998 to 2009 (MDIC, 2012c). Already in 2010, U.S.A. exports of ethanol to Brazil were up about three times more than the total amount exported in the previous 12 years combined (UNICA, 2011). According to Bloomerang (2012), Brazil is struggling to produce enough ethanol to satisfy its own demand.

Figure 47 shows the evolution of the total Brazilian imports and exports of ethanol (to and from all the destinations) since the end of the 1990s.

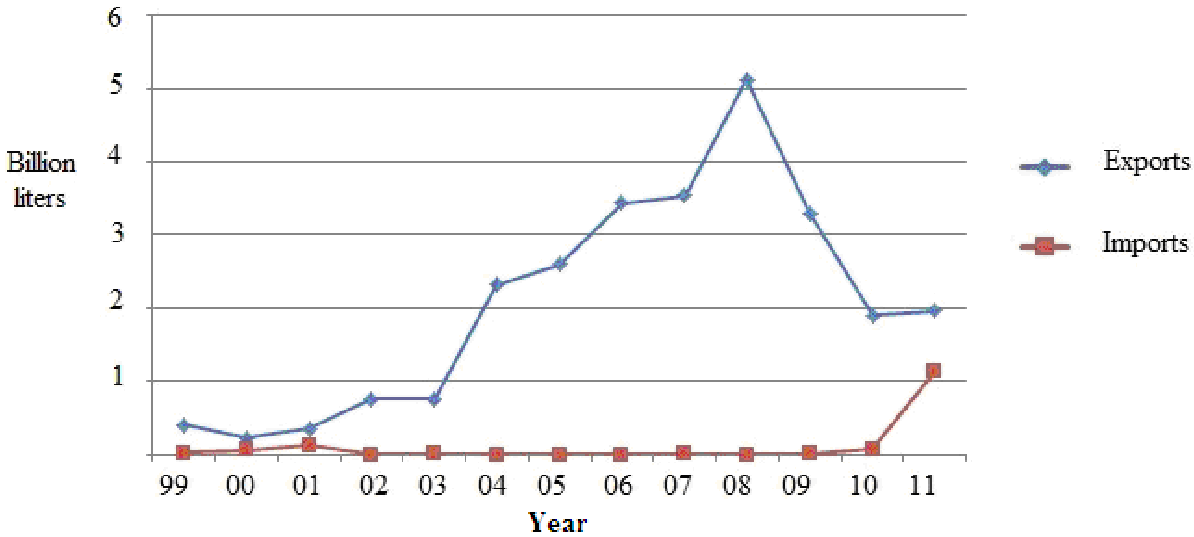

Fig. 47: Evolution of the Brazilian ethanol imports and exports from 1999 to 2011
Source: MDIC, 2012c

IEA disclosed a report that shows that global biofuel consumption can increase from 55 million tonnes of oil equivalent (Mtoe) in 2011 to 750 Mtoe in 2050. The share of biofuels in the global transport fuel is expected to grow from 2% in 2011 to 27% in 2050. IEA predicted that ethanol on its own could make up 10% of world gasoline use by 2025 and 27% in 2050 (IEA, 2011a). The international demand is expected to be driven by country biofuel targets, incentives and mandates and by the increasing demand of the U.S.A., Europe and various Asian countries (USDA, 2011).

In 2009, the European Union Renewable Energy Directive set mandatory targets to be achieved by 2020 including a 20% overall share of renewable energy and a 10% share of renewable energy in the transport sector. It has been estimated that biofuels will represent around 9% of the total energy consumption in European transport in 2020 (SETIS, 2009). Ethanol consumption in the EU is projected to double to 9 billion liters per year in 2020. Brazilian ethanol exports to the EU are projected to reach 1.4 billion liters in this same year, in addition to its exports of feedstock for biofuel production (USDA, 2011).

In 2010 the European Commission announced its scheme for certification of sustainable biofuels aimed at ensuring environmental, social and economic sustainability along the whole supply chain (European Biofuels, 2011). The following certification schemes were recognized in July, 2011:

Table 23: Recognized schemes for certification of sustainable biofuels

Initiative	Promoter	Scope	Specifications
International Sustainability and Carbon Certification Scheme (ISCC)	German Government financed	All types of biofuels	Sustainability aspects along the supply chain of biofuels: e.g. reduction of GHG emissions.
Bonsucro EU	Roundtable initiative	Reducing environmental and social impacts of sugarcane production	Metric based standard to measure the impact of the sustainable production of sugarcane: economic, social and environmental aspects and a set of technical and administrative requirements.
Round Table on Responsible Soy (EU RED)	Roundtable initiative	Aims soy production that is economically viable, socially equitable and environmentally sound	Responsible for soy production in terms of requirements of areas with high conservation value. Promoting better working conditions, best management practices, and respect of land tenure claims.
Roundtable on Sustainable Biofuels (RSB EU RED)	Roundtable initiative	All types of biofuels	Create criteria for the sustainable production of ethanol through establishing parameters for the business.
Biomass Biofuels Voluntary Scheme (2BSvs)	French industry scheme	All types of biofuels	Addressing farmers, biomass agencies, processors and traders. Independent audit.
Abengoa RED Bioenergy Sustainability Assurance (RSBA)	Industry scheme for Abengoa	Covering their supply chain	It is a certification standard allowing the approval of EU Biofuels as sustainable. It focuses in the certification of raw materials and entire process chain which allows the biofuels production.
Greenergy Brazilian Ethanol Verification Programme	Industry standard initiative, developed by Greenergy	Sugarcane based ethanol from Brazil	Applied to sugarcane based ethanol produced in Brazil. The scheme has received recognition for all criteria of the Renewable Energy Directive, except for the provision on highly biodiversity grasslands.

Source: European Biofuels, 2011; ISCC, 2012; Bonsucro, 2012; RTRS, 2012; Bureau Veritas 2012; Avengoa 2012; Greenergy, 2012

Currently, the European Commission is deliberating with other voluntary schemes how to improve their standard to meet the sustainability requirements for biofuels (European Biofuels, 2011).

In U.S.A., the Energy Independence and Security Act of 2007, which comprises provisions for Renewable Fuel Standards (RFS), required fuel producers to consume at least 136 billion liters of biofuels by 2022. The standard establishes a threshold of 57 billion liters of first generation ethanol by 2015 and 80 billion liters or more of cellulosic ethanol and advanced biofuels by 2022 (EISA, 2007).

Global ethanol trade is projected to increase 18% per year from 2011 to 2018, reaching 16.9 billion liters. It has been forecasted that Brazil will supply ca. two-thirds of this demand (USDA, 2011). Over the next decades the OECD/FAO (2011) forecasted a growing share of the production of ethanol to be exported, while most of it will continue to be consumed by the domestic market (Fig. 48). According to these estimates, Brazilian ethanol domestic use is expected to increase up to 41 billion liters in 2020. In terms of ethanol trade, Brazilian ethanol is expected to account for 7% of the global production until 2020 (OECD/FAO, 2011).

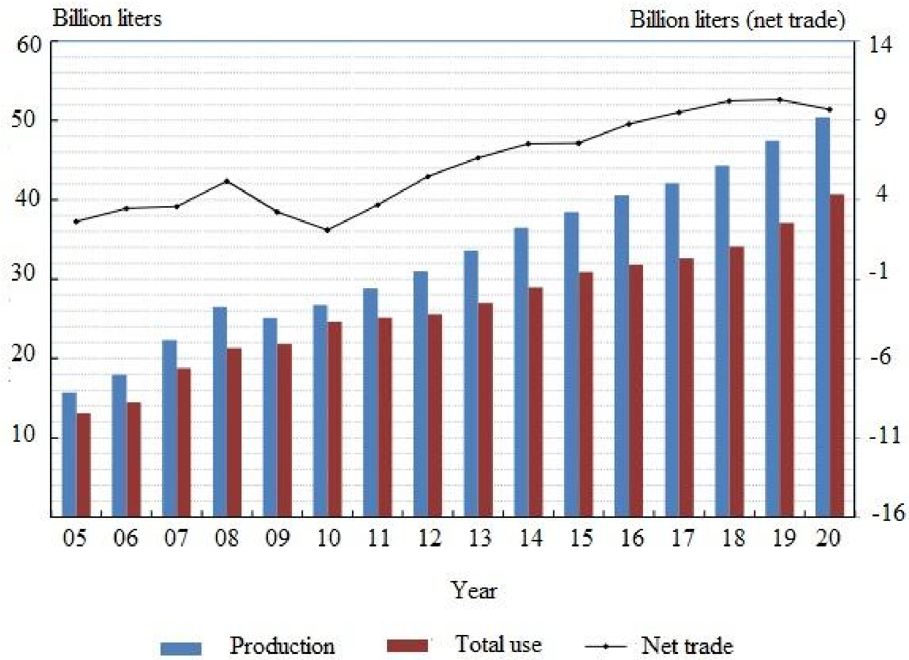

Fig. 48: Projected evolution of the production, consumption and net trade of Brazilian ethanol from 2005 to 2020
Source: OECD/FAO, 2011

From 2010 and until the end of 2011, the Brazilian Government had unilaterally eliminated its tariff on imported anhydrous ethanol (20% on ethanol imports) (UNICA, 2010). In December 2011, the Brazilian Government extended the zero import tariff to ethanol with less than 1% percent water until the end of 2015 (MDIC, 2012d).

USDA (2011) noted that infrastructure and transportation limitations along the supply chain are key hurdles to Brazil's capacity to supply ethanol to domestic and world markets. Investments in infrastructure for both, highways and ports, are expected to contribute to carry out more efficient logistics procedures.

International sugar prices also have a direct effect on the sugarcane agro-industry. UNICA forecasted in 2011 that the production for the harvest 2011/12 in Brazil would have been ca. 40 million tonnes. During the last decade (from the harvest 2001/02) the sugar production has 2-folded (Fig. 49) (UNICA, 2011).

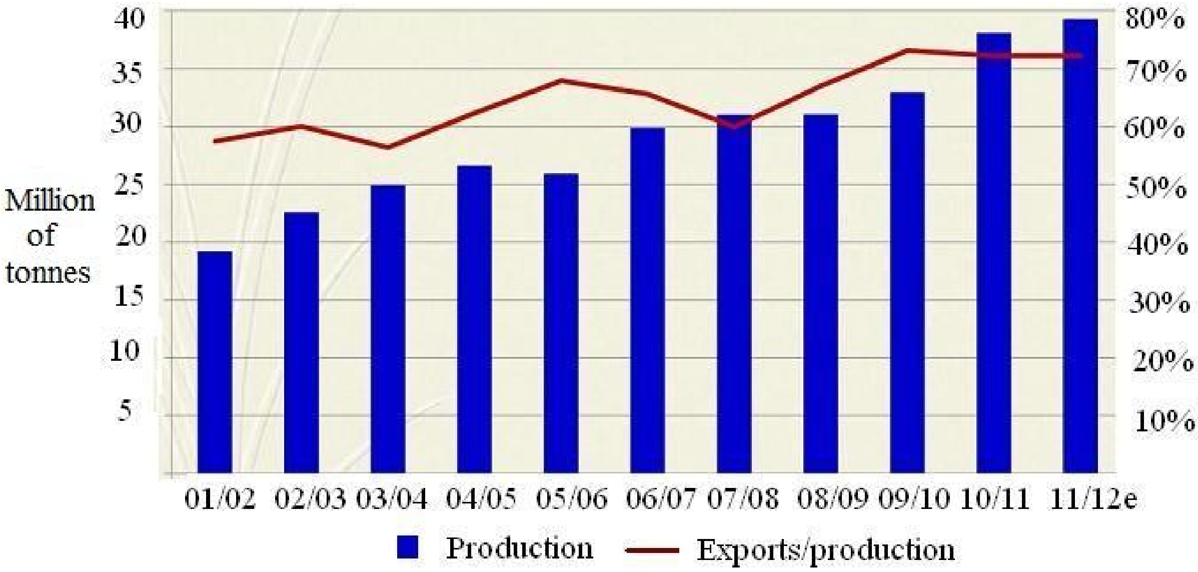

Fig. 49: Evolution of the production and export of Brazilian sugar from 2001/02 to 2011/10 and the projection for 2011/12
Source: UNICA, 2011

Barros reported in 2011 that existing sugar factories made a major expansion while several mills made investments to slightly increase industrial capacity. Furthermore, eight new sugar factories should have started operations in 2011 (Barros, 2011). It has been forecasted that for the harvest 2011/12 Brazil will export ca. 70% of its total sugar production as a consequence of steady high international demand. In the previous harvest (2010/11) Brazil accounted for 50% of the total world's export supplying 128 countries. In 2010 the Brazilian sugar exports summed up 28 million tonnes (UNICA, 2011). According to Barros (2011), sugarcane mills are expected to increase sugar production due to strong sugar prices in international markets. According to MAPA (2011), the production of sugar during the harvest 2020/21 will be 42 million tonnes in comparison to 34 million tonnes in 2010/10.

National and International developments as labor market influencing features

The national market of ethanol and the international market of sugar will be the main determinants of the expansion of the sugarcane production in Brazil. Brazil is a key ethanol supplier of the world trade market. Furthermore, it might be best positioned to fill the growing world demand for ethanol given its ability to expand sugarcane area and its productivity and sustainability advancements (USDA, 2011). In order to sustain its export share, Brazil faces the challenge to maintain its production growth, to satisfy its increasing domestic demand and to produce biofuels considered sustainable by the certification schemes in order to comply with the European requirements. The Brazilian sugarcane agro-industry has evolved along 36 years. Even when sugarcane based Brazilian ethanol might have sustainable advantages compared to other key producers (e.g. U.S.A.), the Brazilian sugarcane agro-industry is a heterogeneous business. Therefore, it is difficult to generalize that ethanol from all the producers could fulfil sustainable criterion. The private and public sector are taking adequacy measures to increase the perspectives to fulfil the international sustainability demand (Sect. 6.2, Sect. 6.6).

The mechanization of the sugarcane harvesting operation could contribute to tackle environmental implications eliminating the practice of clearing land by fire. Nevertheless, in order to contribute to social sustainability, the private sector might have to carry out adjustments of traditional practices to satisfy the demands of an international certification when these have specific references to the job relations and work conditions in the production chain.

6.2 Legislation

Brazil has stringent labor and modern environmental laws in place to which the Brazilian sugarcane agro-industry is subjected. The role of the government for the enforcement to the adherence to these regulations is a key part of the sector's developments.

6.2.1 Labor laws

In Brazil labor laws are consolidated under the CLT (*Consolidação das Leis do Trabalho*). In addition there are also state specific laws regarding contractors and workers. The main objective of the CLT is the regulation of individual and collective work relations. Regarding the occupational health and safety standards, the Brazilian Ministry of Labor has issued norms where most of minimum requirements are established such as the Health and Medical Control Program NR7 (*Programa de Controle Médico de Saúde Ocupacional*) and the Regulatory Norm of Labor Safety and Health in Agriculture NR31 (*Segurança e Saúde no Meio Rural*). The NR31 established that the employer must guarantee the adequate work conditions, hygiene and comfort of the workers and to carry out risk assessments. Furthermore the NR31 considers that employers must provide quality accommodation for migrant workers to supply free and safe transport to the rural work areas, and provide training for workers that apply, handle, transport or are in contact with chemical, agrochemicals and/or operate machinery (UNICA, 2010; Sucre-ethique, 2012). Even when in Brazil rural workers are well provisioned under the law, this does not necessarily imply that these requirements will be implemented (Sect. 6.4).

6.2.2 Environmental laws

The Brazilian Government had established environmental legislations to which agricultural activities are subjected. The Forest Code is mostly related to biodiversity conservation and includes requirements for legal reserves and permanent preservation areas. The National Policy for Water Resources governs the licensing of the use of water for production activities. Agrochemicals, along their whole life cycle are regulated by a federal law. In Sao Paulo, there is a state law in place that deals with soil conservation and preservation of agricultural soil and a technical norm concerned with field storage and vinasse application (Greenergy, 2011; Macedo, 2000).

In 2007 the Government of Sao Paulo, the Ministries of Environment and Agriculture and UNICA signed a cooperation protocol called the Agro-environmental Protocol or Green Protocol. This document sets the commitment to eliminate the sugarcane burning by 2014 for areas where mechanical harvesting is possible and for 2017 for areas where mechanical harvesting is not possible. Prior state legislation set up the deadline for the elimination of the sugarcane burning practice by 2021 in areas where mechanization was possible and by 2031 in areas with land steepness restrictions for mechanization. The Table 24 compares both burning reduction schedules.

Table 24: Federal law and Sao Paulo decree schedules for sugarcane burning reduction

Year	State Law No. 11.241/02		Agro-environmental Protocol	
	Mechanizable areas	Non-mechanizable areas	Mechanizable areas	Non-mechanizable areas
2007	30%	0%	30%	0%
2010	30%	0%	70%	30%
2011	50%	10%	70%	30%
2014	50%	10%	100%	30%
2016	80%	20%	100%	30%
2017	80%	20%	100%	100%
2021	100%	30%	100%	100%
2031	100%	100%	100%	100%

Source: UNICA, 2008

Other points considered in the protocol are the implementation of plans for soil conservation including the combat to erosion and hydric resources and the adoption of good practices for the training of the operators and compulsory use of individual equipment protection.

As the deadlines for the sugarcane burning practice elimination were anticipated (Fig. 50) the Agro-environmental protocol stimulates the modernization of the agricultural activities (Nastari, 2010). According to Aguiar et al., (2011), the technical directives of the Protocol are different depending on the producer category (agribusiness units or suppliers). Under the rules of the Protocol, suppliers are small producers responsible for up to 12,000 tonnes of sugarcane in each crop year from sugarcane fields of up to 150 ha. Even when suppliers represent 92% of the state's producers, they produce only 10% of the sugarcane. It is necessary to distinguish between types of producers to make sure that small suppliers are not excluded from the productive process and have enough time to comply with the Protocol's goals (Aguiar et al., 2011).

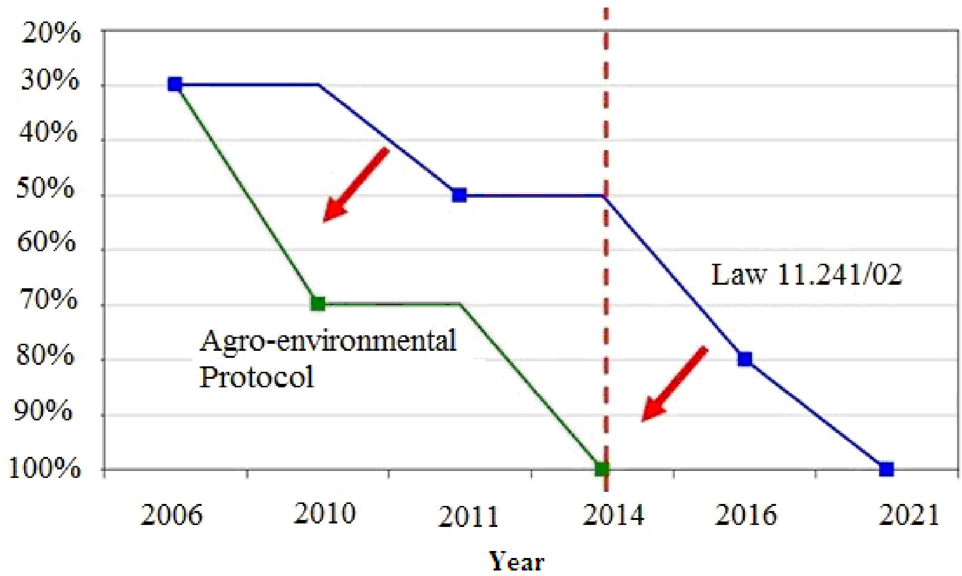

Fig. 50: Proposed percentage of harvested sugarcane without burning under the federal law and the Agro-environmental protocol
Source: UNICA, 2010

According to Coissi (2009), regardless of the acceptance of the Agro-environmental protocol among producers, during the 2008/09 harvest, the proposals issued by the sugarcane mills to burn sugarcane fields encompassed a total of 1048 million ha. Coissi (2009) suggested that this territorial extension represents a decrease of only 11,000 ha from the 1059 million ha requested one harvest before. Nevertheless, as mentioned before, the application procedure for the burning practices is upon authorization from the environmental state authorities to be implemented[22]. According to a recent research study of the Brazilian Institute for Space Research in Sao Paulo during the last five harvest seasons, no significant reduction were observed in the amount of pre-harvest burned land. Aguiar et al. (2011) noted that in Sao Paulo 55.6% of the total area harvested during the season 2010/11 was done without previous burning (Table 25).

Table 25: Sugarcane harvest system monitoring. Sao Paulo, 2006/07-2010/11

Harvest season	Green harvest		Pre-harvest burning	
	Area (ha)	%*	Area (ha)	%*
2006/07	1,110,121	34.2%	2,131,989	65.8%
2007/08	1,767,049	46.6%	2,023,215	53.4%
2008/09	1,924,076	49.1%	1,997,630	50.9%
2009/10	2,234,331	55.5%	1,792,734	44.5%
2010/11	2,627,023	55.6%	2,101,110	44.4%

Source: Adapted from Aguiar et al., 2011
Note*: The percentages refer to the total harvested area in Sao Paulo state during the specified crop year.

It is interesting to note that the difference in area harvested without previous burning increased 136.6% from 2006/07 to 2010/11, while the area harvested with previous burning in 2010/11 even reduced its acreage compared to the harvest of 2006/07. According to Aguiar et al., (2011), this situation is due to the expansion of the sugarcane area which did not cause significant increases in the area harvested with previous burning, since it was entirely compensated by the increased green harvest.

According to Aguiar et al. (2011), based on the current trend, the objectives of the Protocol are likely to be achieved one or two years later (2015–2016), which will be five or six years ahead of 2021, the goal of the Law No. 11241.

Minas Gerais and Goias are other producing states that have also defined specific norms to eliminate the sugarcane pre-burning practice. In Minas Gerais, the State Law No. 10.312/98 established that the terrain with a slope higher than 12% could be mechanized until 2031. In 2008, in Minas Gerais, a protocol similar to the one signed in Sao Paulo was established aimed at eliminating the sugarcane burning practice in 2014. The main difference of the Sao Paulo and the Minas Gerais protocols is the compulsory membership imposed to the producing units of Minas Gerais. According to Gonçalves (2010), during the harvest 2008/09

[22] In order to carry out a pre-harvest burning, in Sao Paulo producers must send the requisition for burning when the harvest season begins. This requisition is evaluated and registered. Afterwards, the producer must inform the burning date and time and to be alert of the level of air humidity, since if the relative air humidity is less than 20%, all burnings are prohibited. Sugarcane burning practice is forbidden close to urban areas, environmental reserves, electrical stations, railways and highways (Aguiar et al., 2011).

in Minas Gerais 36% of the sugarcane harvested was collected mechanically when increasing 13% from the last harvest season (23% in 2007/08).

In Goias the Law No. 15.834/06 established the deadline to eliminate the sugarcane burning until 2028 for areas with a slope lower than 12%. This law does not define terms for the elimination of fire in areas above 12%. During the harvest 2009/10 the mechanization in Goais reached 60% (Gonçalves, 2010).

Legislation as a market labor influencing feature

The Green Protocol will be a key influencing feature of the future developments of the sugarcane labor market, as it fosters a more rapid adoption of mechanization. Labor laws' enforcement will also be a crucial element of this transition as mechanization does not inherently imply that the social sustainability of the sugarcane supply chain will improve. Even when workers operating mechanical harvesters will have less physical demands compared to manual sugarcane harvesters, the adherence to the legislation has to be surveilled.

6.3 Agricultural trends

The planted area of sugarcane in Brazil had increased significantly from 1990-2010 (Fig. 51). Particularly from 2003, the planted area of sugarcane started a period of expansion. This year coincides with the introduction of flex fuels cars in Brazil.

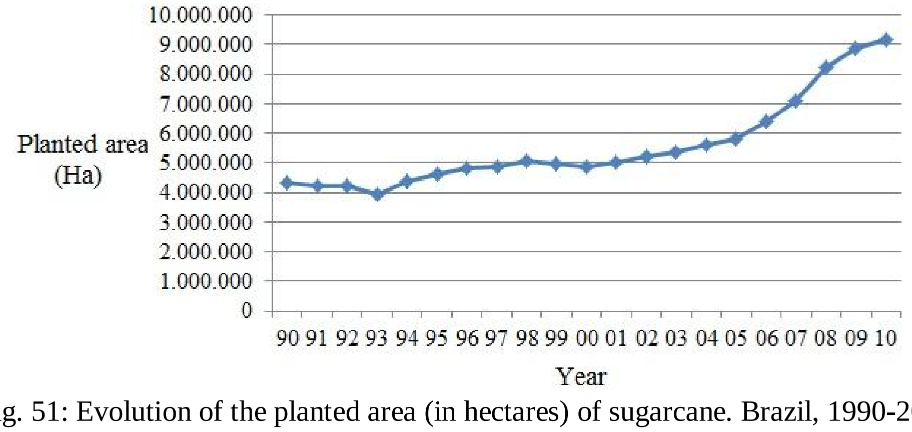

Fig. 51: Evolution of the planted area (in hectares) of sugarcane. Brazil, 1990-2010
Source: IBGE, 2012

From 1990 to 2003 the average growth rate was 1.99 % and from 2003 to 2010 the average growth raised to 8.48%. The total sugarcane planted area in Brazil increased more than 2-fold in 2010 (9.16 million ha) compared to the levels of 1990 (4.32 million ha). Figure 52 below shows the planted area evolution of sugarcane in comparison to other cultures.

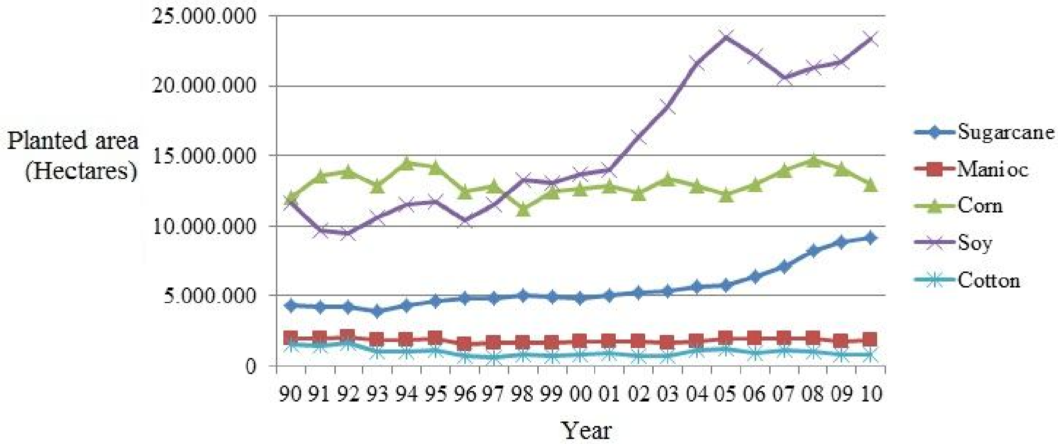

Fig. 52: Evolution of the planted area (in hectares) of sugarcane and other selected crops. Brazil, 1990-2010
Source: IBGE, 2012

In Brazil, the total land occupied with crops is expected to expand 6 million ha by 2020/21 (EPE, 2011). This area expansion is expected to be concentrated in two cultures: soy, with an augment of 5.3 million ha, and sugarcane, with an increase of 2 million ha. According to Cunha (2007), besides soy, cotton and beef cattle are activities that compete with sugarcane for area expansion.

The amount of sugarcane produced showed a growth rate of 4.91% and went from 262.7 million tonnes in 1990 to 717.46 million tonnes in 2010 (Fig. 53).

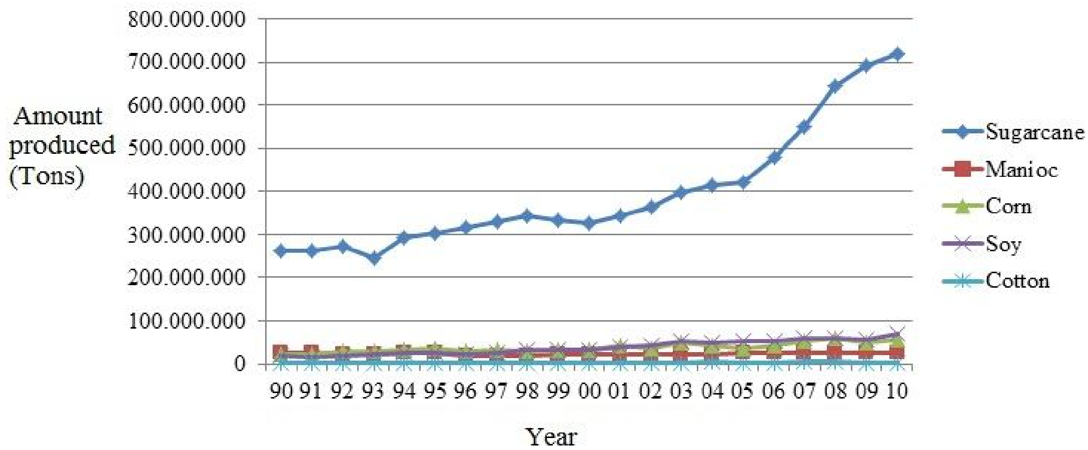

Fig. 53: Evolution of the production (in tonnes) of sugarcane and other selected crops. Brazil, 1990-2010
Source: IBGE, 2012

Until the 1980s, temporary crops such as soy and sugarcane were responsible for absorbing large amounts of workers (Goldemberg et al., 2008). The amount of workforce demanded (men/year) (EHA- *Equivalente Homem Ano*) per 100 hectare of sugarcane and other cultures are shown in the Table 26.

Table 26: Workforce demand (in men/year for 100 hectares) of workers of sugarcane and other selected crops in 2000

Activity	Number of jobs	Activity	Number of jobs
Soy	2	Manioc	38
Sugarcane	10	Coffe	49
Bean	11	Orange	16
Rice	16	Tomato	245

Source: Noronha, 2006

From the beginning of the 1990s the number of salaried workers occupied with sugarcane activities decreased (Fig. 54). Conversely, from 2001, it is possible to note a slight increasing trend certainly associated with the expansion of the sector. Therefore, it seems reasonable to conclude that the expansion of the sugarcane production activities has to some extent compensated the reductions of workforce demand.

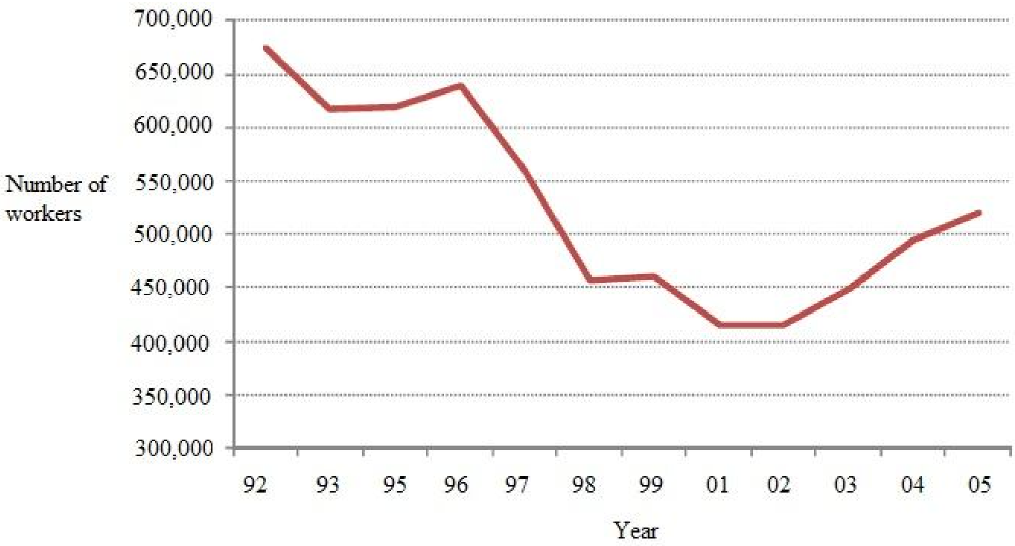

Fig. 54: Evolution of the number of salaried workers in the sugarcane production. Brazil, 1992-2005
Source: PNAD, 1992-2005, apud Cardoso, 2010

In general, the trend of the agricultural sector is to become less labor intensive regardless of its expansion in area and production given the increases in productivity. Sugarcane is among the cultures that had shown the largest reductions in the demand of workforce per hectare in the last years together with coffee, grains and oilseeds (IEA[2], 2009) (Table 27). The employment reduction of sugarcane during the period analyzed (1992-2007) was more significant than that of coffee (11%) and soy (18.7%) but was surpassed by the reduction levels of manioc (28.5%), corn (41.6%), and rice (46%). Even with the decreasing trend observed, sugarcane is the culture with the highest number of agricultural workers in Sao Paulo (IEA[2], 2009).

Table 27: Evolution of the production, planted area and employment of sugarcane and other selected crops. Brazil, 1992 and 2007

Crop	Production (Million tonnes)			Planted area (Thousand ha)			Workforce (Number of workers)		
	1992	2007	Var. (%)	1992	2007	Var. (%)	1992	2007	Var. (%)
Sugarcane	271.4	549.7	102.4	4,224.5	7,086.8	67.7	674,630	527,401	-21.8
Manioc	21.9	26.5	21.1	2,031.5	1,941.1	-4.5	205,963	147,293	-28.5
Corn	30.5	52.1	70.8	13,886.8	14,010.8	0.9	435,892	254,609	-41.6
Soy	19.2	57.8	201.1	9,463.6	20,571.3	117.4	143,336	116,454	-18.7

Source: IBGE, 1992 and 2007; PNAD 1992 and 2007, apud Oliveira, 2009

IEA[2] (2011) developed workforce demand projection scenarios based on the characteristics of the land where the production expansion has been driven in Sao Paulo. This study considered that the amount of workforce demanded is a ratio of 8 men/year for each 100 ha under the current mechanization conditions. The first scenario projection considered a sugarcane productivity of 85.7 tonnes/ha and assumed that by 2030 the sugarcane planted area in the state of Sao Paulo will evolve from 4.9 million ha to 7.9 million hectares, corresponding to the demand of 633 thousand workers, having an increase of 238 thousand men/year units compared to current levels (from 395 thousand men/year units to 633 thousand men/year units). A second scenario assumed a productivity increase of 1.2% per year and its results showed that in 2030 the planted area in Sao Paulo will reach 6.1 million ha, representing a demand of ca. 493 thousand men/year units. An increase of 98 thousand jobs compared to current levels (Fig. 55).

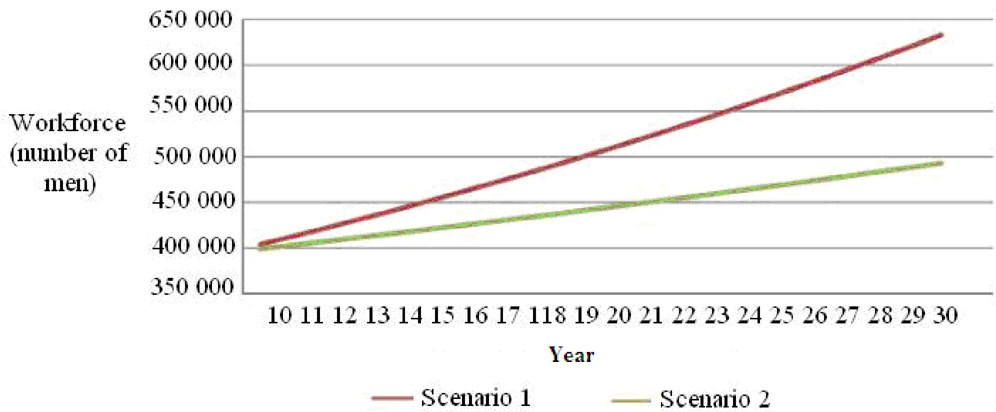

Fig. 55: Projection of workforce demand for sugarcane production with a constant productivity (scenario 1) and with a productivity increase rate of 1.2% per year (scenario 2). Sao Paulo, 2010-2030
Source: IEA[2], 2011

The IEA[2] also constructed two more scenarios for the production of *cana energia*[23] in Sao Paulo. The projections of a first scenario showed that maintaining a constant level of productivity (100 tonnes/ha), in order to achieve a production of 678.3 million tonnes in 2030, 6.8 million ha would be necessary implying an evolution from 395 thousand men/year units in 2010 and 546.6 thousand men/year units by 2030. The second scenario considered that the average productivity would growth by 1.2% per year. Under this assumption, in order to obtain the same production the occupied land would be 5.3 million hectares corresponding to 422.4 thousand jobs.

Agricultural trends as labor influencing factors

Agricultural workforce demand is directly related to the performance of the agricultural production. The trends of employment will depend on a combination of area planted, production and productivity levels.

The advancement of other mechanized cultures in the Center-West regions such as cotton and soy creates even more competition to find qualified workforce for the sector. Furthermore, during the last years the agricultural sector also had to compete with the employment opportunities offered in urban areas according to personal interviews with industrial managers of a production unit.

6.4 Working conditions

Various research studies have been carried out in order to investigate the evolution of the job conditions in the sugarcane agro-industry. It seems to be a consensus that significant improvements took place in several socioeconomic indicators over the years. Basaldi (2007) suggested that these improvements were the consequence of the pressure of the organized syndical movement and of the effective enforcement of labor laws. Moraes (2011) suggested that the large exposure of Brazil in international markets had probably prompted the private sector to have greater concern for social issues.

Some of the main improvements documented in the literature are related to increased job formality, improved benefits received from the employers, increased schooling (Sect. 5.4), the reduction of child labor (Sect. 5.5) and real salary gains (Sect. 5.6).

During the last decades, there has been an increasing trend to formalize the work relations of agricultural activities in general. The work and social security card (*CTPS*) grants the workers

[23] This sugarcane variety is more efficient from an energy point of view than the sugarcane varieties used currently given its sucrose and fibre content In addition, fibre could also be used for the generation of electricity (e.g. through hydrolysis), increasing its efficiency.

with benefits in terms of access to retirement and other rights, such as paid overtime and medical care. These formal jobs are protected by the labor legislation (MTE, 2012).

According to Basaldi (2007), sugarcane production is one of the agricultural activities with the highest levels of employment formality. In 2005 from all the permanent sugarcane workers with urban residence 89.6% had the register card (this share was 75.3% in 1992). This level was higher than the average of the Brazilian agricultural sector, which was 32.1% in 2005. In 2005, from all the permanent workers with rural residence, the share of formal workers accounted for 68.4%, while it accounted for 73.9% for temporary workers with urban residence and 47.1% for the temporary workers with rural residence. These indicators were 60.3%, 47.9% and 19.3% in 1992. When considering these indicators, it is possible to notice that permanent workers tend to have higher levels of formality compared to temporary workers. Rezende (2006) tried to give an explanation to this phenomenon by establishing a link with the costs incurred by the employers. Formality levels of the temporary workforce is lower than those of permanent agricultural workers because high administrative costs are largely invariable regardless of the size of the workforce. As being fixed, the unitary costs are higher for temporary workers than for permanent ones (Rezende, 2006).

Moraes, et al. (2011) suggested that in 2008 in Brazil, the share of formal workers from the total sugarcane employees (81.4%) was higher than that of agriculture in general (less than 40%) (Fig. 56).

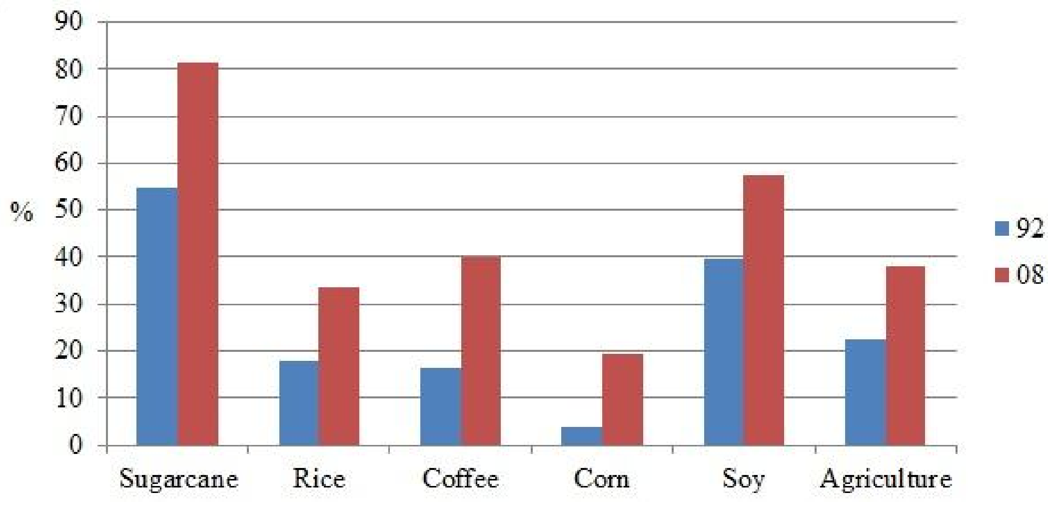

Fig. 56: Evolution of the proportion of formal workers in sugarcane and other selected crops. Brazil, 1992 and 2008

Source: Adapted from data from PNAD, 1992 apud Oliveira, 2009 and PNAD, 2008 apud Moraes et al., 2011

Even when the entire activity has undergone improvements in terms of formality in all the regions, there are still sharp differences among them (Fig. 57).

Moraes (2005) noted based on data from PNAD that in Brazil, on average, 37.2% of all the sugarcane rural workers were formal ones in 1981. During this same year (1981) the share of formal sugarcane workers in the North-Northeast regions was 35.1%, in the Center-South it was 40.7% and in Sao Paulo state it was 40.5%. In 2007, these figures increased to 66.5%, 90.3% and 95% respectively (Oliveira, 2009).

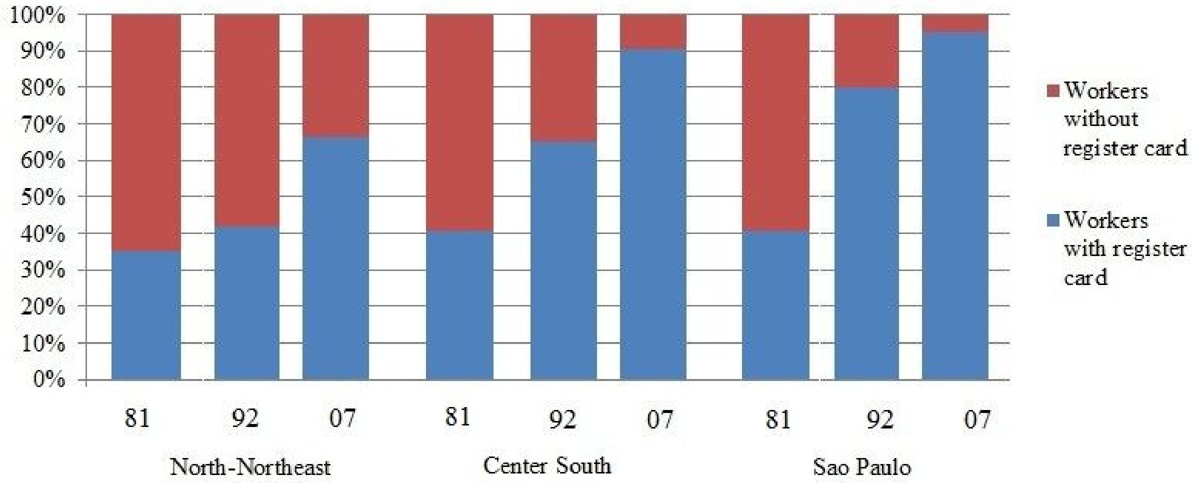

Fig. 57: Evolution of the regional differences of the share of sugarcane workers with register card, 1981, 1992 and 2007
Source: Adapted from data from PNAD, 1981 apud Moraes, 2005; and PNAD, 1992 and 2007 apud Oliveira, 2009

It is interesting to note that in 2007 even when the sugarcane workers from the North and Northeast regions had a lower formality rate than the workers from other regions, this share is still above than the levels of the soy, coffee, rice, corn, manioc and the entire agriculture by that time.

Rural workers interviewed by the authors pointed out the importance of the formalization of labor relations in order to have direct contracts between workers and enterprises without intermediaries (the so-called “gatos”[24]) (Aguiar, pers. comm., 2011).

Regarding the benefits received, it is possible to highlight that during the last decades major improvements have taken place in transportation and food aids, the accommodation support especially for the rural residents and the health services particularly for the permanent workers with urban residence (Basaldi, 2007). The social benefits, such as the work conditions vary from company to company (UNICA, 2012).

One of the key tools of the Brazilian Government to guarantee the adequacy of working conditions is a "Special Mobile Inspection Group[25]" including labor inspectors, federal police

[24] The *gato, turmeiro or empreiteiro* is an informal intermediary between the agricultural worker and the employer. The juridical figure of this intermediary is not defined by the law (Rezende, 2006).
[25] Grupo Especial de Fiscalização Móvel no setor sucroalcooleiro.

and attorneys from the federal labor prosecution branch. This group audits workplaces, looking for labor irregularities (MTE, 2012). Since the group's creation in 1995, irregularities have been identified affecting sugarcane workers. Some of these irregularities are: excess of working hours, lack or inadequate individual protection equipment, poor quality and insufficient meals, problems with hygiene and comfort (lack of sanitary facilities and drinking water), unsafe and accident-prone transportation, among others (MTE, 2012). These cases and other irregularities are examples of violations of the Brazilian labor laws.

The workers' union leaders interviewed by the author noted that there are also isolated cases in which sugarcane rural workers were embedded in a compulsory work relation with their employer based on debts associated with transportation, accommodation and food. The Federal Law No. 5.889/73 allows a deduction from the salary of up to 20% to cover accommodation and a deduction from the salary of up to 25% to cover meals (If previously authorized and agreed by the worker). The worst cases of labor relations in the sector are associated with offences as serious as slavery.

UNICA (2011) have recognized that currently there are still isolated cases of workers in conditions analogous to slavery in the rural sector as there are in other production spheres such as coal. The Brazilian Ministry of Labor draws up a list[26] of companies with slavery offences which is disclosed by NGOs. These cases have been detected in large corporation groups and also in small production scale. According to Rezende (2006), this measure could affect negatively the small producers, because if they were fined for non-compliance, depending on the case, they could even have to stop their operations.

The last update made to the list was in the end of December 2011. By then 294 names were registered including individuals and legal entities (MTE, 2012). From this total, 10 violators (7 located in the Center-West, 2 located in the Northeast, and 1 located in the Southeast region) were related to the sugarcane agro industry summing up 2,581 workers. These workers were identified in diferent federal entities: Mato Grosso do Sul (44%), Goias (6.3%), Ceara (5.4%), Mato Grosso (25.5%), Espirito Santo (3.1%) and Alagoas (15.5%) (MTE, 2012).

One of the main instruments against the cases of slavery is the National Pact for the Eradication of Slave Labor launched in 2005 which aims to avoid that the business sector and the Brazilian society market products from suppliers who used slave labor (Reporter Brasil, 2012).

[26] *Cadastro de Empregadores que tenham submetido trabalhadores a condições análogas à de escravo* commonly referred to as the slave labor "dirty list" (*lista suja do trabalho escravo).*

The National Commitment to improve labor conditions in the sugarcane activity (*Compromisso nacional para aperfeiçoar as condições de trabalho na cana-de-açúcar*) was launched in 2009 by the Brazilian Government, UNICA, FERAESP and the National Confederation of Agricultural Workers (CONTAG). The national commitment aims to identify a set of good business practices in the production units. The National Commitment deals with: (i) business practices such as the work contracts, hiring migrant workers, transparency in measuring production, labor health and safety, etc., and (ii) commitment to promote literacy, qualification and strengthening social actions and services in the regions of origin of the temporary migrants (Government of Brazil, 2012). Industry members that had voluntarily adhered to the program can receive a conformity certificate if they comply with 30 guidelines based on best practices, which are more rigorous than the legal obligations of the federal laws. More than 300 sugar and ethanol producers (ca. 75% of the total industry input) adhered to the Commitment since it was launched. The program deadline is in June 2012, when all the participants should comply with its requirements.

Work conditions as a labor market influencing feature

Although the industry had made notable progress in improving work conditions UNICA (2011) have acknowledged that there is still room for improvement, which should be promoted both by employers and the public sector. The working conditions vary largely from region to region and even from company to company. As the sector is away from being homogeneous, it is impossible to generalize it.

One aspect that deserves further attention would be the fact that most of the producers currently reported for slavery offences are located in the Center-West of the country, where the production is expanding. It would be interesting to investigate the reasons of these developments. The outsourcing of agricultural workers, for instance, could represent a risk for non-compliance of existing legislation if the sugarcane producers do not monitor the practices of their service providers (Greenergy, 2011).

6.5 The pace of mechanization

According to FAO (2012), mechanization is one of the most controversial technological innovations in agriculture, as it is associated with the loss of rural jobs worsening an already marked tendency to rural–urban migration. Among different authors, it is possible to identify conflicting points of view stating the advantages and disadvantages of agricultural mechanization. Nevertheless, this dissertation considers that mechanization is a necessary innovation that will have a wide range of impacts which in turn will be associated with challenges and opportunities. Based on the previous chapters, it seems reasonable to assume that mechanization of the sugarcane harvest is a natural choice of the productive sector mainly due to the economic benefits, linked to the possibility to operate the mechanical harvesters 24 hours and the elimination of the uncertainties associated with the availability of the workforce. Furthermore, mechanization could be an appropriate strategy to ease the access to external markets of ethanol to countries with strict environmental legislations as the technology currently available is able to harvest sugarcane without being previously burned.

The combined automotive harvester for chopped sugarcane works by moving in the lines, and cutting the tops with the top cutter (Fig. 58). The crop divider, fin roller and the knockdown roller are part of the feeding system and position sugarcane for the cut which is carried out by two rotating discs with blades. After the cut, the feed rollers do the internal transport of the complete stems which are raised towards the choppers that grinds the sugarcane and the impurities are withdrawn through the primary extractor. The elevator raises the stems to the superior part where a second cleaning procedure takes place by the secondary extractor for posterior unloading (Lionço et al., 2010).

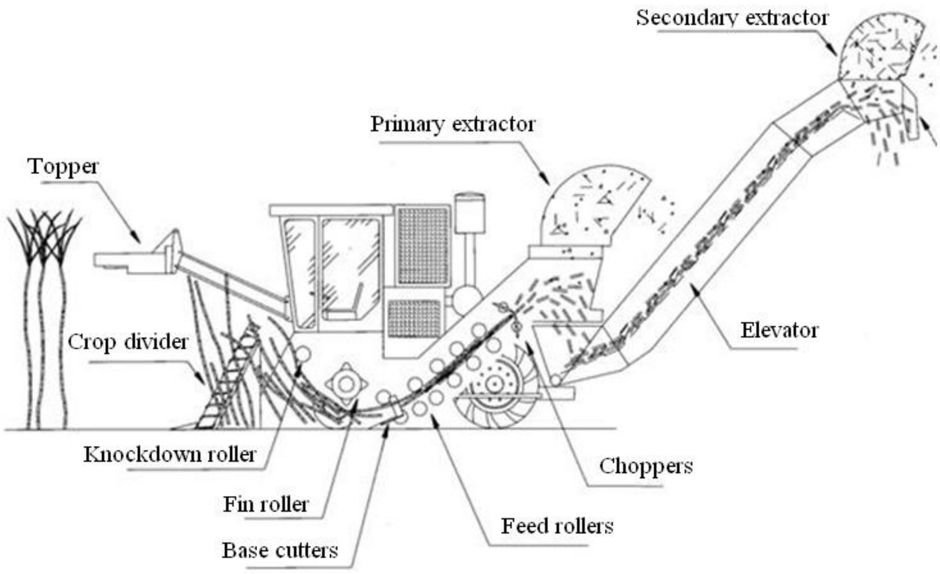

Fig. 58: Major components' diagram of a sugarcane harvester
Source: Lionço et al., 2010

The evolution of the mechanization in Brazil varies widely among regions, states and even among municipalities (Table 28 and Table 29). The Table 28 compares the evolution of the mechanical harvest share (from the total area harvested) in Sao Paulo, the Northeast and the Center-South region.

Table 28: Evolution of the share of sugarcane area harvested mechanically. Brazil, by region, 1994-2007

Year	Northeast	Sao Paulo	Center-South	Brazil
1994	-	-	-	4
1997	3.2	17.8	15.4	13.5
1998	5.7	26.4	24.9	23.8
1999	5.9	22.3	25.3	23
2000	7.6	30.5	28	24.7
2001	8	33.2	31.2	29.7
2002	9.1	35.5	32.5	31.8
2005	9.6	35.4	33.3	
2006	9.9	36.2	34.8	
2007	10.7	40.7	38.2	

Source: Moreno, 2011

For the harvest 2010/11 the share of sugarcane harvested with the green cane system in Sao Paulo reached already 55.6% (Aguiar et al., 2011). According to Moreno (2011), the state has an advantage as it already has infrastructure to support the mechanization such as workshops to repair the machines and other authorized enterprises. Currently, the state of Mato Grosso has the largest index of mechanical harvesting and also the highest percentage of sugarcane harvested without prior burning 78% and 69% respectively (CGEE, 2009).

Table 29: Evolution of the share of green harvested sugarcane. Sao Paulo, by administrative region, 2006/07-2010/11

Administrative region	06/07	07/08	08/09	09/10	10/11
Aracatuba	33.4	47.3	55.4	56.8	58.3
Barretos	23.1	41.7	44.8	61.7	63.9
Bauru	31	42	42.5	50.4	47.5
Campinas	40.3	54.7	51.7	60.8	53
Central	36.4	51.3	48.6	61.4	60.1
Franca	29.9	45.7	47	51.2	54.4
Marilia	28.1	38.9	43.1	43.7	54.1
Pres. Prudente	21.3	51.7	59.9	49	50.2
Riberao Preto	38.7	46	48.9	56.6	57.6
S. Jose R. Preto	44.5	46.7	49.9	59.9	57.7
Sorocaba	41.8	45.1	48.4	57.9	52

Source: Adapted from Aguiar et al., 2011

According to Moraes (2007), there are three factors which influence the adoption rate of the mechanization in Brazil: (1) The slope of the cultivation areas (2) The capital availability (3) The organized workers' union movement, since in the areas with higher degrees of organization, the workers have more influence and bargaining power in the salary negotiations and other parameters ruling the interactions of capital and work (Sect. 5.2).

Lionço et al. (2010) noted that in order to implement the mechanization of the harvest operation it is necessary to verify that the defined harvest plots do not have a slope higher than 12% since declivity is a limitation for the machines currently available in the market. It is expected that in the future new equipment will enable the mechanical harvest in lands with higher declivity (Lionço et al., 2010).

According to Moreno (2011), 70% of the Center-South region could be mechanized while in the North and the Northeast only 30% of the cultivated area could be mechanized due to the sharp slope mainly in the state of Pernanbuco and the North of Alagoas. Sao Paulo has an important advantage since it is estimated that 94.6% of the area planed could be mechanized (Moreno, 2011).

Mechanization involves that changes are undertaken in the systemization of the area (Lionço et al., 2010) and the logistics of the production system, since the whole dynamics in which sugarcane is collected and transported to the producing unit changes.

Regarding the capital availability, Smeets et al., (2008) suggested that the implementation of mechanical harvesting has been limited in part by the high investment costs associated with the harvester machines (Table 30).

Table 30: Characteristics of mechanical sugarcane harvesters available in the Brazilian market

Producer	Model	Capacity	Fuel consumption	Price	Maintenance	Lifespan
John Deere	3510	100,000 tonnes/harvest	40 l/hour	R$860,000	R$60,000/year	7 years
Santal	Tandem	100,000 tonnes/harvest	36 l/hour	R$700,000	R$49,000/year	8 years
IH	7000	120,000 tonnes/harvest	40 l/hour	R$800,000	R$80,000/year	7-10 years

Source: Moreira, 2006

According to Lino (2009), until 2006 the sugarcane mechanical harvesters were able to harvest up to 750 tonnes of sugarcane in 24 hours. After the harvester John Deere 3510 was launched, this capacity increased to more than 1,000 tonnes of raw sugarcane in 24 hours.

Besides the initial investment costs, maintenance costs are associated with the purchase of mechanical harvester machines. The maintenance costs of the machines vary depending on the duration of the harvest period, the amount of hours worked per day, the kind of terrain in which it is operated and its operation among other factors (Moreira, 2006).

Large producers have more economic resources to invest in technology than small producers. In addition, small areas require that the machines do more maneuvers implying more expenses in fuel and more time in the operations (Moraes, 2007).

According to Lino (2009), in 2007 the fleet of sugarcane harvesters in Brazil was between 1.2 and 1.3 thousand units, but half of them were already more than 8 years old. The sales of sugarcane mechanical harvesters had a sharp increase during the last years (Table 31).

Table 31: Evolution of the sales (in units) of sugarcane mechanical harvesters in Brazil from 2003 to 2010

Year	Sugarcane harvesters sold
2003	40
2004	58
2005	142
2006	313
2007	645
2010	1,000[(1)]

Source: Lino (2009), Gonçalves (2010) [(1)]

Alves et al. (2011) noted that in 2008, due to the global economic crisis, one third of the sugarcane agro-industry experienced difficulties and financial re-structuration. Investments in modernization and machinery purchases reduced hindering the mechanical harvest intensification also due to the reduction of credit lines by the banks. According to Gonçalves (2010), the market for sugarcane harvesters in Brazil dropped 30% in 2009. Nevertheless, Gonçalves (2010) also noted that the downturn in sales of cane harvesters was temporary and the demand of harvesting machines is likely to expand in the next years.

FAO (2012) noted that the rapid expansion in farm machinery motivated the development of local machinery manufacture, to the point where Brazil is now a major producer of farm machinery. According to Lino (2009), in Brazil there are three main producing enterprises: John Deere, Case and Santal, being the first two multinationals covering 90% of the market and the later one, national.

According to FAPESP (2011), a new technological solution called *controlled traffic structure* is being developed at the National Laboratory of Bioethanol Science and Technology (CTBE) to carry out all the mechanized operations of the sugarcane farming cycle. This machine will reduce traffic on the planted area resulting in less soil compaction and will be able to remain stable in places where the gradient is as high as 19%.

The pace of mechanization as a labor market influencing feature

IEA[2] (2008) estimated that the introduction of sugarcane harvester machines un-employs ca. 2,700 workers per harvest for each 1% of the mechanized area in Sao Paulo[27]. The type of technology adopted and the pace of mechanization will be key determinants of the demand changes of workers. For instance, Braunbeck & Oliveira (2006) compared the current

[27] For this calculation, IEA[2] used the information of the surveys from 2007, considering the amount collected on average per worker, the sugarcane yield and the harvest period length (assuming 132 days actually worked).

mechanical harvesting and a semi-mechanical harvesting[28] proposal for a quick spreading of green cane harvesting on hilly areas, with lower impact on agricultural labor and farmers investment capacity. Braunbeck & Oliveira (2006) estimated that the use of mechanical assistance technology would result in a sustainable potential demand of 33,000 workers which would operate in areas that are considered non-mechanizables. On the other hand, the mechanical assistance technology is linked to the challenge of managing larger amounts of workers and might not be attractive to large producers, but could be an opportunity for suppliers with lower investment capacities (Braunbeck & Oliveira, 2006).

Regarding the adoption pace, Novaes et al. (2011) suggested that sugarcane is a dynamic culture. The future developments and trends of the sugarcane mechanization will be influenced by economic variables, political stability, ethanol and sugar price, demand of the agricultural machinery, etc.

6.6 Agro-environmental zoning

The Agro-environmental Zoning for sugarcane (National ZAE) emerged to define priority areas for expansion of agricultural activities due to sugarcane suitability and environmental concerns (Andrade & Miccolis, 2011). The Decree nº 6.961/2009 approved the initiative and determined the National Monetary Council[29] to establish the rules of financing/credit operations for the sugarcane sector according to its terms (Government of Brazil, 2009).

According to this decree, the objective of the zoning is to foster the sustainable sugarcane expansion and production. Using digital processing technologies, an assessment of the sugarcane production potential was carried out taking into consideration the climate, soil type, temperature, precipitation levels, etc. to identify lands where sugarcane could be grown in rainfed conditions (without full irrigation).

In order to indicate the most suitable lands for expansion, the following areas were excluded: (i) terrains with a declivity superior than 12%, (ii) areas with native vegetation cover, (iii) the biomes Amazon, Pantanal and Bacia do Alto Paraguai, (iv) environmentally protected areas, (v) indigenous lands, (vi) forest remnants, (vii) dunes, (viii) wetlands, (ix) cliffs and rock outcrops, (x) reforestation, (xi) urban and mining areas, and (xii) areas already cultivated with sugarcane in Goias, Minas Gerais, Mato Grosso, Mato Grosso do Sul, Parana and Sao Paulo.

[28] The semi-mechanical harvesting method developed by UNICAMP includes mechanical aid equipment to assist manual harvesters. The mechanical aid equipment would perform the basic cutting operations, remove and compact the leaves and stems, and stack them into piles. Manual workers would be responsible for withdrawing the stems from the “rolled” sugarcane and determining of the point where the cut should be made by the pointer.

[29] The National Monetary Council in Brazil is presided by the Ministry of Finance. The council is responsible for establishing the rules of credit and monetary policies.

The areas indicated by the sugarcane Agro- environmental Zoning comprise those currently in intensive and semi-intensive agricultural production, special crops and pastures classified by their current use. According to the results of these studies, Brazil has ca. 63.5 million ha (ca. 7.5% of the Brazilian territory) suitable for the expansion of the sugarcane production, being considered from these 18 million ha with a high productive potential, 41.2 million ha with medium potential and 4.3 million ha with low potential. The pasture areas suitable for the expansion in 2002 accounted for 36.1 million ha. UNICA had estimated that ethanol production could triple if 2% of existing degraded pastures were replaced with sugarcane fields (Chaddad, 2010). Figure 59 shows the suitability of areas for sugar cane expansion in Brazil according to the Agro- environmental Zoning. In this figure, the suitable areas are indicated with the range of green colors.

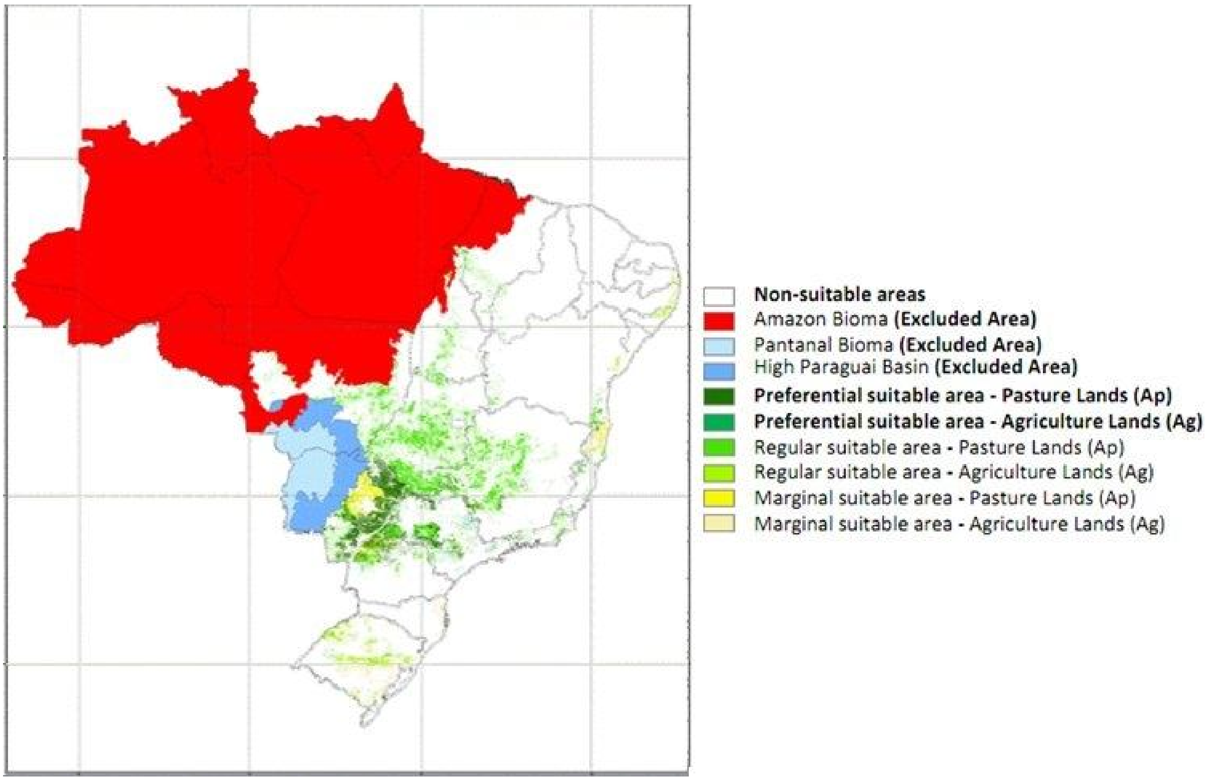

Fig. 59: Agro-ecological Zoning map
Source: Government of Brazil, 2009

According to Leopold (2010), the sugarcane Agro-environmental Zoning is an innovative environmental policy that can be used to shift agricultural production onto a more sustainable pathway. Notwithstanding that the zoning is an important development, it has also received criticism. It has been pointed out that the zoning largely ignores biodiversity aspects since there is a lack of restrictions for sugarcane expansion in the mega-biodiverse Cerrado (Reporter Brasil, 2009; Andrade & Miccolis, 2011; Greenergy, 2011). Furthermore, sugarcane plantations currently in progress, and the scheduled expansions, even in protected areas cannot be prohibited. In addition, the further expansion of the sugarcane for the production of cachaca, brown sugar, animal feed and other products than sugar and alcohol are not included in the constraints (EMBRAPA, 2010). Andrade & Miccolis (2011) also noted that despite the zoning, sugarcane expansion can put pressure on land and transform the landscape of sensitive ecosystems in regions outside its limits.

Leopold (2010) noted that the Agro- environmental Zoning defines clear rules for stakeholders interested in expanding sugarcane production and strategically uses financing and processing pressure points for enforcement. Nevertheless, regardless of the careful design of this measure, its enforcement on Brazil's vast agricultural frontiers will be the key for its effectiveness (Andrade & Miccolis, 2011).

The sugarcane's zoning is expected to increase the acceptance of the Brazilian ethanol in the world markets since the inclusion of the environmental issue in the sugarcane zoning process shall play a differentiation factor in favor of Brazilian products (Government of Brazil, 2009).

The Agro-ecological Zoning as a labor influencing feature

In Brazil, the sugarcane expansion is expected to be steered by environmental legislation. The Agro-ecological Zoning will then, play a key role in the labor market developments of the Brazilian sugarcane agro-industry as it will define the geographical allocation of the workforce demand. The agro-business projections from the Brazilian Ministry of Agriculture for 2020/21 were disclosed in 2011 and considered the evolution of the agricultural sector in a national and regional scale. In national terms, these predictions forecasted that by 2020/21 the production of sugarcane will increase by 24.6% compared to the 2010/11 harvest going from ca.750.1 million tonnes to 934.6 million tonnes. In regional terms, sugarcane projections were calculated for six federal states (Goias, Minas Gerais, Mato Grosso, Parana and Sao Paulo) (Table 32).

Table 32: Evolution of the sugarcane production and planted area. Brazil, by regions, in 2010/11 and the projection for 2020/21

Federal state	Production (Million tonnes)			Planted area (Thousand ha)		
	2010/11	2020/21	Variation (%)	2010/11	2020/21	Variation (%)
Goias	52.08	74.01	42.1	624.1	885.4	41.8
Minas Gerais	64.30	82.66	28.6	783.2	974.9	24.5
Mato Grosso	16.55	21.57	30.4	236.5	299.4	26.7
Parana	55.62	71.93	29.3	658.8	838.6	27.3
Sao Paulo	441.88	574.42	30	5,172.3	6,682.3	29.2

Souce: Adapted from MAPA, 2011

These regional projections indicate that in 2020/21 the greatest increase in sugarcane production compared to 2010/11 will occur in the state of Goias (42.1%). In addition, Goias will also be the frontrunner in terms of expansion of planted area with ca. 42% of increase. When analyzing this report, it is noticeable that assumptions were undertaken regarding an increase in productivity since it forecasted that from 2010/11 to 2020/21 the national sugarcane production will augment 24.6% while the planted area should only expand 18.2%. To conclude, it is important to note that the developments of the expansion of the sugarcane agricultural frontiers will be influenced by a compound set of variables. Nevertheless, such forecasts can provide an overall idea of how the regional distribution of the workforce demand will take place.

6.7 Intermediate conclusions: Labor market influencing features

After analyzing the labor market influencing features, it was possible to conclude that mechanization will induce (i) qualitative, (ii) quantitative, (iii) geographical, and (iv) temporal changes in the labor dynamics. The national and international markets will indirectly define the amount of workers that will be demanded by the sector as their developments steer the production and area expansion rates (quantitative). Furthermore if new international markets are developed, specific sustainability standards might be set in place influencing the job conditions and employment characteristics (qualitative). Labor legislation will safeguard that the job characteristics are adequate in the sector (qualitative). Environmental legislation will influence the timeframe for mechanization implementation on specific areas (temporal) and will also allocate the workforce demand depending on the categorization of mechanizable and non-mechanizable areas (geographical). Agricultural trends refer to the area, production and productivity variables and their interactions. The amount of workforce demanded by the sector will depend on the evolution of these variables (quantitative). The sugarcane agro-industry is a heterogeneous sector. The differences in working conditions could play an important role when workforce decides where (or where not) would they prefer to settle (geographical). Furthermore, the work conditions of the productive units could have an impact in their perspectives to accede to international markets influencing so their development perspectives. The pace of mechanization will determine the rate in which the workforce demand will change, either when there is a reduction of non-specialized workers or when there is an increased demand of specialized ones (temporal, quantitative). In addition, the pace of mechanization will also influence the amount of workers demanded, depending on the technology adopted (quantitative). The Agro-environmental Zoning will steer the expansion of the sector in geographical terms.

Chapter 7

7. Matching

Chapters 5 and 6 already explored the capacity and labor market influencing features identified for the construction of the framework. In order to bridge these two elements, the objective of this chapter is to identify the cause and effect relationships among their components. Sect. 7.1 illustrates them in a feedback loop diagram. Sect 7.2 discusses the expected impacts of mechanization in the jobs' characteristics. Sect 7.3 analyzes the existing qualification strategies. The matching process will enable the identification of the specific areas where strategic interventions are needed.

7.1 Feedback loop analysis

According to Sundkvist et al. (2005), feedback can be defined as the influence that conveys information about the outcome of a process or activity back to its source. This means that a system component can itself be influenced indirectly by the changes it has induced.

Feedback loops can be used as control devices in socio-economic systems as feedback can be transmitted and made visible through relatedness between people, agreements (institutions) or through spatial or temporal localization (Sundkvist et al., 2005).

In order to integrate the complex set of interactions taking place in the Brazilian sugarcane agro-industry dynamics around the mechanization of the harvest a feedback loop diagram was constructed (Fig. 60). The diagram does not take into consideration the externalities of the system (e.g. general national and international economic situation, political instability, etc.). The second order effects were also not considered. This feedback loop diagram is prone to uncertainties and is based on assumptions that will be explained as follows.

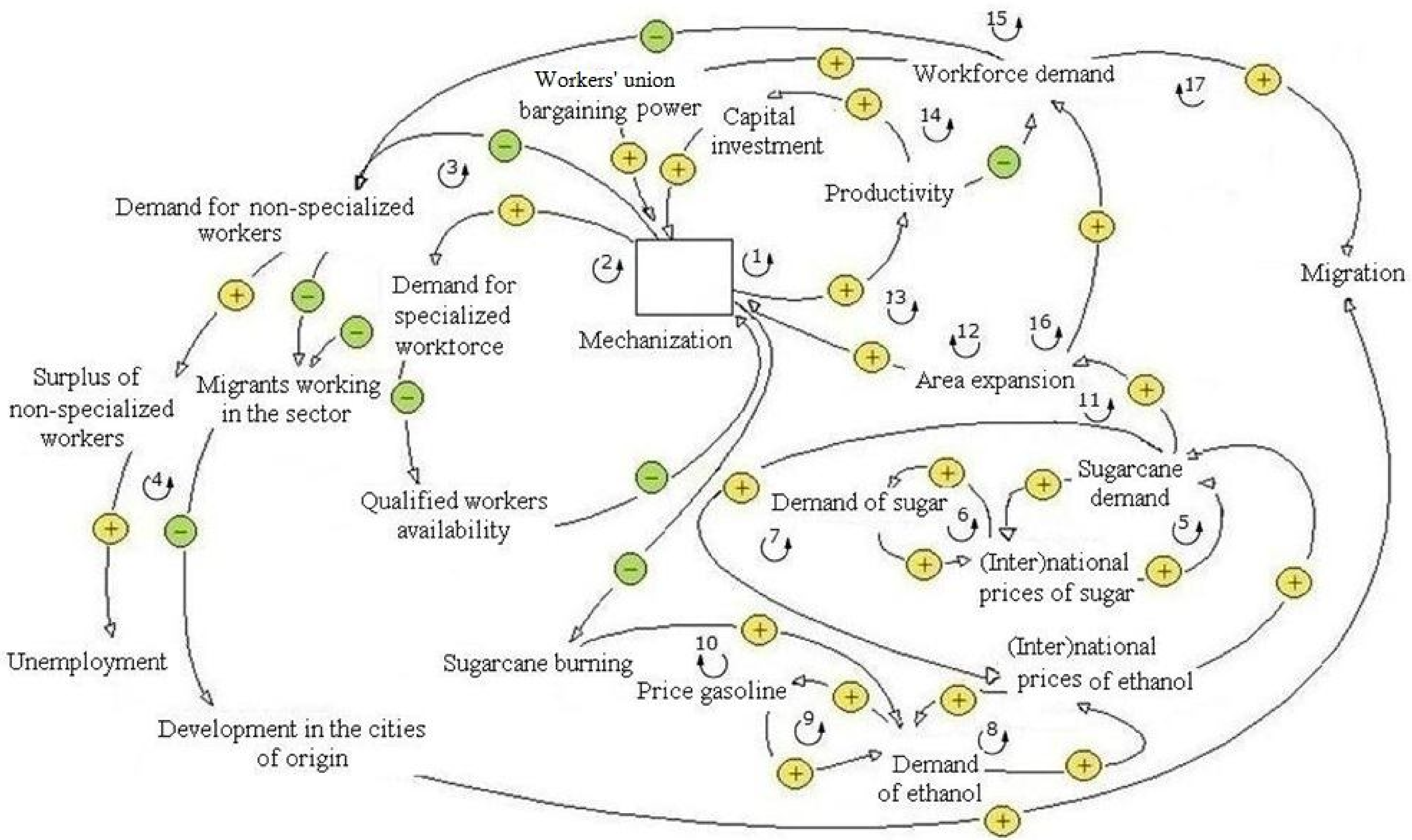

Fig. 60: Sugarcane harvest mechanization feedback loop diagram

Loop 1: It could be assumed that mechanization increases the industry's productivity. As productivity increases, the industry has an increase in economic resources, from which at least a portion could be used as capital investments to finance more mechanization efforts.

Loop 2: Mechanization of the sugarcane harvest will increase the demand for specialized workers. Most likely, the enterprises will prefer to hire specialized local workforce from the producing regions, instead of hiring migrants. In addition, in general, the migrants from the deprived regions of Brazil tend to be non-specialized. Therefore the number of migrants working in the sector is expected to decrease due to their lack of specialization (Loop 3). As the demand for specialized workers increases, there will be a reduction in the availability of qualified workforce. If there are not enough qualified workers to carry out the mechanization activities, the pace of mechanization of the enterprises might be decelerated (at least in regions where mechanization is not an obligation).

Loop 3: Mechanization of the sugarcane harvest will decrease the demand for non-specialized workers. Migrant workers tend to have the lowest levels of formal education and therefore they could be the most vulnerable group to be dismissed. This situation will affect negatively the development of their cities of origin, as these regions will stop receiving the income from the dismissed workers and the levels of unemployment will increase. These adverse conditions in the cities of origin increase emigration pressure, fostering migration flows to other regions (and no longer to sugarcane regions).

Loop 4: As the demand for non-specialized workers is reduced, there will be a surplus of non-specialized workers. This trend will increase the unemployment of workers with low qualifications that will have problems to be reabsorbed into other economic sectors.

Loops 5 and 6: The loop 5 considers the sugarcane demand as a function of the dynamics of the prices of sugar, which in turn are influenced by the demand of sugar (Loop 6) in both, national and international levels. In Brazil, the sugar domestic market has remained almost stable during the last years, and therefore what most importantly impacts the demand of sugarcane is the international market.

Loops 7, 8 and 9: The loop 7 considers the sugarcane demand as a function of the dynamics of the prices of ethanol, which in turn are influenced by the demand of ethanol (Loop 8), which in turn is influenced by the price of gasoline (Loop 9). It is important to note that for these loops, the domestic market dynamics are more relevant than the international ones.

Loop 10: The mechanization of the sugarcane harvest reduces the amount of sugarcane being burned before its collection. If the amount of sugarcane harvested with previous burning decreases, the international acceptance of Brazilian sugarcane ethanol could increase, increasing its demand (because of a better GHG balance). In addition, mechanization is also expected to reduce labor relations' problems.

Loop 11, 12, 13, 14, 15, 16 and 17: The loop 11 considers that if the demand of sugarcane increases, there will be an expansion in the area used for its production. There are two possibilities: (i) that the sugarcane produced in the new area will be collected mechanically (Loop 12, 13, 14 and 15), or (ii) that the sugarcane produced in the new area will be collected manually (Loop 16 and 17). There are less probabilities that the sugarcane produced in the new area will be collected manually.

Loop 12 considers the mechanized scenario. It assumes that as mechanization increases productivity (Loop 13) there will be a reduction of the demand of workforce (in general) (Loop 14). This situation will foster a reduction on the demand for non-specialized workers (Loop 15).

On the other hand, the Loop 16 assumes that the sugarcane produced in the new area will be collected manually, increasing the demand for workforce. This trend will on the one hand increase the bargaining power of the unions, which might foster the adoption of mechanization. Contrarily, it will increase the demand for manual sugarcane harvesters, fostering migration flows to fulfill the industry's workforce requirements (Loop 17).

7.2 Expected impacts of mechanization in employment

The mechanization of the harvest is expected to have impacts on the jobs' characteristics. Even when the exact effects will depend on many factors, some hypothesis can be drawn to better approach the problem.

7.2.1 Status of the job position (Permanent / Temporary)

Rezende reported in 2006 that the dimension of the temporary agricultural labor market in Brazil was smaller than that of the 1970s and 1980s. During the last years, the significance of the permanent salaried jobs had increased as a consequence of the mechanization of the Brazilian agriculture (Sibien, 2010).

Even when the mechanization of the sugarcane harvesting operation is expected to foster the creation of permanent job opportunities for specialized workers while reducing the demand for temporary non-specialized workers, the exact increase of this indicator is difficult to quantify. The creation of permanent labor links will depend on the specific needs and strategies of the employers.

According to Macedo (2007), in 2005 the share of permanent sugarcane agricultural workers was 56.6%. Thirteen years before (by 1992) 70% of the soy workers had a permanent labor link with the employer, probably due to the high level of mechanization (Oliveira, 2009). Permanent jobs could also reduce the worker's rotation. According to Goldemberg et al. (2008), the rotation share of sugarcane is much more above the rotation average in formal works of the country (which by 2005 were 60% and 43%, respectively). High rotation leads to low qualification of the workforce. During the personal interviews with industrial and agricultural managers, instability has been pointed out as one of the factors that inhibit the qualification efforts of the employers. This statement was supported by Rezende (2006) who suggested that within the temporary salaried rural labor market neither the employer nor the employee had an incentive to invest in the workforce qualification. The creation of permanent jobs could reduce migration flows (Silva, pers. comm., 2011).

On the other hand, the social convenience of permanent jobs for some groups has been questioned (Sibien, 2010; Rezende, 2006). According to Rezende (2006), the seasonal nature of these jobs could be an advantage for family agricultural workers from low income regions in Brazil since they offer an alternative to complement their activities, without the risks associated with small scale agricultural production. Furthermore, the temporary labor market could also be an important source of income for the family secondary income providers. This group is significantly integrated by women or aged individuals mainly in urban environments, as the main family workers prefer to avoid agricultural jobs due to their seasonality.

During the inter-harvest period the agricultural and industrial machinery might require maintenance. Nevertheless, the portion of workers that remain hired in the sector notwithstanding its seasonal operation is very small. According to the findings of Fredo (2011) the percentage of dismissals (from the total number of admissions) of mechanization workers and non-specialized agricultural workers in Sao Paulo in 2009 did not show significant differences (93.3% and 98.6% respectively).

7.2.2 Salary implications

In principle, it would be expected that more qualified occupation categories were associated with higher income due to their higher level of specialization. Various studies about the topic had backed this assumption. For instance, Lino (2009) estimated 3 income equations to evaluate the effect of specialization on the individual's income in the sector using data from PNAD from 2002 to 2007. The results from this paper, shown that the influence of specialization was confirmed as in three models, specialized workers earned 22.2%, 21.7%, and 21.7% more than their non-specialized counterparts. In one of these equations, the coefficient of the schooling variable was expected to increase 0.9% of the salaries for each additional year of schooling up to 10 years, and 10.2% afterwards. Even when other variables (such as the formality status) of the workers shown a higher impact on the income equations (up to 36.1% higher income compared to informal job positions); Lino (2009) concluded that the importance of education to increase the income of sugarcane workers in Sao Paulo was evident.

Fredo (2011) considered the remuneration structure of the entire sector in 2009. According to data from CAGED in 2009, from the total number of mechanization workers' admissions the largest share (77.7%) earned from 1.51 to 2 minimum salaries while for the non-specialized agricultural workers the largest proportion (92.7%) earned from 1.01 to 1.5 minimum salaries (Fig. 61).

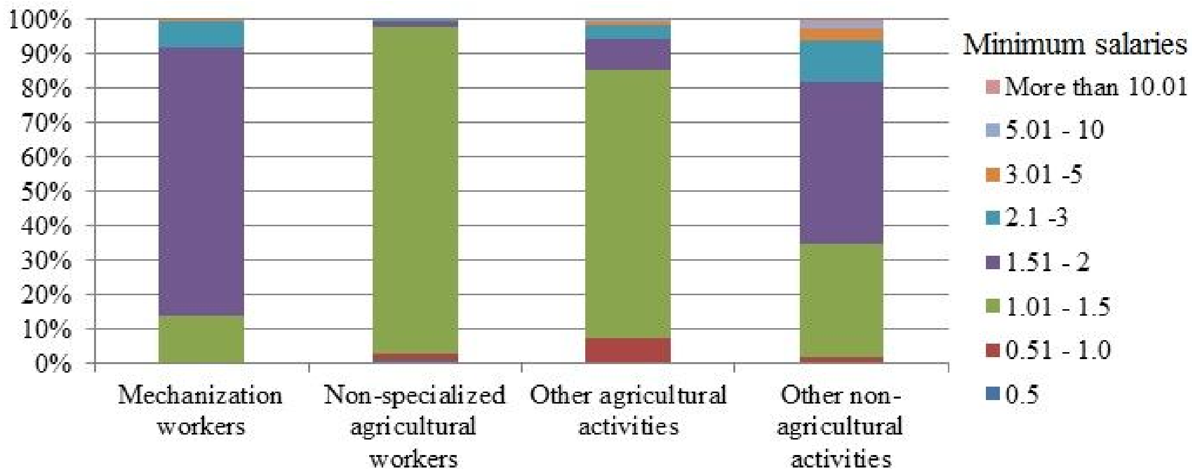

Fig. 61: Admissions' structure of various occupation categories of the sugarcane-agro-industry by remuneration (in minimum salaries). Sao Paulo, 2009
Source: Adapted from data from CAGED, 2009, apud Fredo, 2011

As the mechanized harvest is further adopted replacing the manual harvest system, the average income of the agricultural workers is expected to rise.

7.3 Qualification strategies

According to Fredo (2011), the adoption of new technologies has the immediate effect of eliminating job positions and on the other hand there is a certain time lag in the creation of new job positions due to the new functions demanded. According to MTE (2010), the lack of qualified workforce for satisfying the requirements of the sector had different reasons. It was noted that for instance, in some Northeaster localities the demand was driven by the emigration of workers to the South, Southeast and Center-West regions. In other regions of the country the scarcity of qualified workforce has been associated with the increasing mechanization trend and the accelerated expansion of the sector (MTE, 2010). In order to tackle this defy initiatives have risen.

Sugarcane Agro-industry National Qualification Plan *(Plano Nacional de Qualificação para Setor Sucroalcooleiro)*

The Sugarcane Agro-industry National Qualification Plan launched on 2010 had the objective to qualify more than 25,000 workers in all the country by the end of 2011 (MTE, 2010). During the first stage of the program from the 12,600 workers to be qualified 61.6% were related to industrial occupations while the remaining 38.4% was related to agricultural workers. Admission requirements vary depending on the occupation but are focused on alphabetized workers. Its objectives are summarized in Table 38.

Table 33: Distribution of the qualification objectives of the National Qualification Plan

Federation unit	Total number of workers	Total agricultural workers	Total industrial workers
Alagoas	1,005	450	555
Paraiba and Rio Grande do Norte	627	170	457
Pernambuco	1,794	695	1,099
Goias	1,774	300	1,474
Mato Grosso and Rondonia	1,222	386	836
Mato Grosso do Sul	897	330	567
Minas Gerais	1,390	480	910
Sao Paulo	2,833	1,294	1,539
Parana	1,058	738	320

Source:MTE, 2010

During a personal interview with the Director of the Department of Sugarcane and Agroenergy from MAPA it was noted that other programs supporting the inclusion of disadvantaged groups were taking place such as alphabetization course for adults (offered sometimes by the municipal government entities), access to electric energy, bank inclusion and housing programs. Furthermore, there are other qualification programs focused of federal entities which are also focused in the workers for the sugarcane agro-industry.

Clean Cane Program *(Programa Cana Limpa)*

The program *Cana Limpa* from the National Rural Training Service (SENAR - *Serviço Nacional de Aprendizagem Rural*) aims the workforce qualification in the various steps of the agro-industry supply chain, with the objective to optimize all the production stages of the sugarcane. According to IEA[2]-APTA (2009), ca. 85,000 sugarcane harvesters had already participated in the program from 2004 to 2005. In 2006, the goal was to train 1,400 workers.

According to a personal interview with a representative of SENAR, more recently courses for the operation and maintenance of automotive harvesters have been launched. According to this representative, these courses are offered on demand and the industry solicitor has to provide the harvester required for the training. This course requires only 48 hours (6 days) from which 40 hours are with the complete group and for the rest with 2 or 3 participants in practical activities. The representative interviewed highlighted that the applicants of the program have to be older than 18 years old and to be literate.

Renovation Program (*RenovAção*)

This project is a partnership between Unica, FERAESP and supply-chain companies with support from the Inter-American Development Bank (IADB). The project provides specialized training for approximately 3,000 workers per year in six of the major sugarcane producing areas in Sao Paulo. The program comprise two modules: one focused on training for mechanized activities of the sector, the other designed to train members of communities that will be impacted by the process of substituting the workforce. The second module includes courses on horticulture, garment making, plumbing and others (UNICA, 2009). According to the latest report of activities from UNICA (2011) until the end of 2011 a total of 4,150 sugarcane harvesters completed professional qualification programs from the introduction of the program in 2009. From this total 56% are already employed in other occupations of the sugarcane agro-industry (UNICA, 2011). These qualification programs require the participants to be alphabetized.

Strategies adopted by the productive units

Companies in the sector have already developed various isolated activities to qualify sugarcane harvesters. According to UNICA, more than 5,000 workers are currently being benefited from such programs (UNICA, 2010). In a personal interview with a representative of the industry, UNICA had knowledge of about 150 projects in the state of Sao Paolo. These strategies are developed either independently or in clusters, with or without cooperation with technical schools, SENAR and/or SENAI[30]. These strategies have been designed mainly to overcome the bottleneck caused by the scarcity of qualified workers. According to Liboni (2009), various companies have focused in developing their own human resources, before hiring external personnel.

According to Carrara (2009), additional difficulties have been faced by the new facilities that have been recently opened in the expansion areas (Center-West). The strategy adopted by some companies with more than one productive unit is to temporally relocate the local

[30] National Service for industrial training (SENAI- Serviço Nacional de Aprendizagem Industrial).

workers (of the new unit) in an already operating one in order to receive training. Some producing groups temporarily relocate their employees for training up to one year (Liboni, 2009).

Another strategy adopted by the sector is to provide financial support (scholarships) to encourage the rural workers to take qualification courses with external institutions. According to Cardoso (2010), in some production units partial scholarship programs are opened for all the employees of the facility including rural workers in order to invest in short duration courses, technical or superior degrees.

Even when there is a trend not to hire migrants and to reduce the manual harvesters, some productive units offer alphabetization courses for migrants. According to Liboni (2009), to qualify the migrants is a challenge due to the limited duration of their stay during the harvest season. On the other hand, new programs are offered by some productive units also in the inter-harvest period. Even when the migrants could not benefit from these programs, the permanent residents of producing areas could.

Other strategies include remote qualification programs for occupations such as the mechanical harvester and manual harvest coordinator offered by CTC (*Centro de Tecnologia Canavieira*) and courses to operate mechanical harvesters offered by the suppliers of the equipment (CTC, 2011).

According to Liboni (2009), in the sugarcane agro-industry, the lack of qualified workforce is not restricted to those associated with the mechanization of the harvest. Liboni (2009) noted that various production units have also shown the concern about finding management professionals and technicians in atomization and industrial chemistry.

7.3.1 Challenges of the qualification strategies

The revision of these initiatives shows that even when various interests groups are taking measures to solve the problem of qualified workforce scarcity, some concerns raise.

When taking into consideration the strategies of the companies, even when the production units may give priority to their own human resources, the low schooling levels of most of the manual harvesters might encourage them to recruit external personnel instead. In such case, the company would save economic resources that otherwise would have to invest probably from the alphabetization of their workforce. According to Alves & Adissi (2011), one of the deficiencies of these initiatives is that it has not been detailed what would happen to the not qualified workers as they will be dismissed when the mechanization expands.

Chapter 8

8. Conclusions

This last Chapter is divided in three Sections. Sect. 8.1 corresponds to the main outcome of this dissertation which is a set of policy recommendations. This section reaffirms some of the most important findings of this research work in a general way. Sect. 8.2 provides key conclusions of the capacity and labor market influencing features analyses which led to the development of the policy recommendations. Remarks about the methodology adopted are also included. Sect. 8.3 illustrates the strategic axis of intervention within the feedback loop diagram constructed. Sect. 8.4 gives suggestions for further research work.

8.1 Policy and strategic recommendations

Until recently, the sugarcane agro-industry has been acknowledged for absorbing large amounts of low qualified workers as it heavily relied on manual harvesters to carry out labor intensive activities. The mechanization of the sugarcane harvesting practice will have profound impacts on the labor market dynamics. On the one hand it leads to a decrease of the demand of non-specialized agricultural workers, particularly manual harvesters. On the other hand, mechanization induces a demand increase of workers with higher qualification. Currently, one of the major constraints to the expansion and modernization of the sector is the lack of qualified workforce. In an attempt to bridge this gap, partially coordinated qualification strategies had emerged.

Several strengths have been recognized in the approach undertaken so far for promoting qualification. Nevertheless, one of the main reasons identified for the difficulties of the productive units to find qualified workforce has been the fragmented approach to qualification issues. Furthermore, most of the current qualification endeavors greatly exclude the workers with the lowest education levels.

Even when mechanization will foster the creation of a number of additional jobs (e.g. in the utilization of the sugarcane trash for electricity generation) the sector will not be able to create enough jobs to relocate its current rural staffing. This problem gains complexity when considering the profile of the majority of these workers. A large portion of these workers are temporary migrants from deprived regions of Brazil. Migrant workers are the most vulnerable group as they are being excluded from the qualification programs aimed to relocate the non-specialized workforce in more specialized occupations. In addition, workers with the lowest levels of schooling (whether migrants or not) are susceptible to the unemployment associated with the demand reduction of manual sugarcane harvesters as they could not take part easily of the qualification strategies. The adverse of the situation is aggravated for illiterate workers.

On the other hand, the participation of women in sugarcane agricultural activities has been reduced over the years. If dismissed from the agro-industry, women will have fewer chances to take part in qualification programs available.

In general in Brazil, there is a trend in the agricultural sector to become less labor intensive regardless of its expansion in area and production. The opportunities of the workers dismissed from the sugarcane culture to be absorbed into other rural activities are also being reduced. In addition, the changes undergone by the sector have been accelerated due to the introduction of environmental laws phasing out the sugarcane burning practice in various federal entities. Under this light, the Brazilian sugarcane agro-industry faces the challenge of conciliating the modernization of its agricultural sector with a socially sustainable transition.

The qualification of these workers would enable them to have better employment perspectives in the agro-industry, in an ideal case, or in other sector. Nevertheless, the disadvantaged economic situation of the North and Northeast regions of the country could also hinder their reincorporation to the salaried labor market.

As the transition towards mechanization occurs, a part of the workforce formerly concentrated in the manual harvest might be transferred to new, more specialized occupations. Detached qualification strategies could compel the labor market to experience shortages (in initial stages) or surpluses (when stabilization had been reached, in specific regions) of these workers.

The inability of the productive units to find specialized workforce could even hold back the expansion of the sector. On the other hand, when these dynamics become more stable and the sector had reached its full capacity, an excessed of specific occupations could decrease the salaries of the workers.

On the other hand, if coordinated policies in a number of separate but linked areas and plans for their implementation were developed, the labor supply and demand of the Brazilian sugarcane agro-industry might be more constructively linked when dealing with economic, energy and sustainability goals.

8.1.1 The creation of the “National Committee on Rural Qualification”

The complexity of the problem under study goes beyond the unemployment associated with the demand reduction of manual sugarcane harvesters. Hence, the suggested solutions are linked to further social and economic sectors.

In order to better understand the complexity of the problematic, a multidisciplinary team could be integrated including: representatives from the Ministries of Environment, Agriculture (and its division of Agro-energy), Labor and Trade, financial institutions, industry representatives, workers' union, rural training institutions and research & development centers. In this way it would be possible to take into consideration the points of view from the stakeholders involved. The strategies developed calls for coordination and coherence across institutions and would cut across environmental, economic, energy and social issues.

8.1.2 Strategic Axes of Intervention

Qualification programs focused in the residents of the producing regions

- Development of a diversified, impartial and development-oriented qualification programs based on the specific needs of the sugarcane agro-industry (quantitative) and the specific workforce profile demanded (qualitative). The coordination of various interest groups could enable this strategy to provide in a timely manner, workers with the required qualification in the locality of demand. In order to develop effective programs, it would be necessary to profoundly analyze the socio-economic characteristics of the workers identified as qualification targets. On the other hand it will also be important to know the profile of the more specialized workers in the specific occupation categories. These analyzes should be done in a regional basis, given the sharp social and regional differences of the country.
- Positive discrimination strategies. These measures could be adopted to promote the relocation of vulnerable groups (e.g. quotas for women or elder workers in qualification programs and/or specific specialized occupations). Another strategy could be the implementation of payroll taxes benefits for the employers of these groups.
- Upgrading training sessions for specialized rural workers. This measure could also be conducted in the sector to ease the professional growth of specialized workers. Such courses could be offered at educational institutions or carried out in company in cooperation with SENAI and SENAR.
- Development of monitoring plans. It would be important to define plans and mechanisms to evaluate the efficiency of the qualification programs (e.g. including fair and systematic selection of workers to be qualified). The committee branch in charge should closely work with rural workers and industry representatives to improve the qualification strategies based on their assessment.
- A consideration that would be regarded as ideal would be that at least a share of these qualification programs were focused on activities, outside the sector, comparable with the RenovAção Project of UNICA. An alternative to reduce costs of these programs would be

to impart remote courses on diverse disciplines. A job bank of vacancies of other sectors could ease the transference of rural workers with urban residence to other demanded occupations.

In summary, it is expected that the coordination of the institutions and training facilities and increasing the quality of the training delivered, could improve the linkages between supply and demand.

Harmonization with other objectives

- Coordination of qualification strategies with environmental initiatives. In federal entities that still don't have a Protocol for phasing out the sugarcane fields' burning practice, an option would be to develop in advance a synchronized calendar aimed at (i) ensuring that the production units will supply their forecasted workforce demand the next harvest season, and (ii) informing the workers in a timely manner if they will not be retained by the sector the next harvest season. The ideal case would be to provide training for them (e.g. alphabetization courses or courses focused on occupations other than the sector) in the inter-harvest period at least one year previous to their dismissal.
- Prioritize the absorption of workers currently working in the industry. Either to set a quota or to define payroll taxes benefits for the reabsorption of internal workers in the sector. Furthermore, these workers should also be prioritized when planning bioenergy projects requiring rural jobs (e.g. use of sugarcane trash for electricity generation).

Increasing the skill levels of human resources should be a major priority while promoting the harvest mechanization. Political commitment will be very important to place the qualification subject high on the agenda.

Policies in the regions of origin of the temporary migrant workers

As mentioned before, the most susceptible group to unemployment is the unqualified migrant workforce. As being dismissed from the sugarcane agricultural activities in the producing regions, migrant workers and their cities will lose economic inflows. Their situation is even more fragile as for these workers it will be difficult to find a job in their region of origin, the reason for which they started migrating in the first place. There is a risk that these migrants will migrate to urban areas which might lead to the expansion of slums. Urban poor are a vulnerable group as they are mainly net food buyers and spend a significant part of their salaries in staple food.

It is necessary to assess and approach the development threats of the regions with high out-migration flows (the major sources of migrant sugarcane harvesters) in order to reduce emigration pressure and encourage return of migrants to their regions of origin. On the other hand, it is important not only to target specific regions but also to identify particular sectors or population groups that are characterized by a high propensity to migrate (e.g. age group). If the living conditions in these rural settings are enhanced, it could be possible (in some extent) to influence migration flows.

- Encourage return of migrants to their regions of origin. When considering the lack of opportunities and the social inequality in the regions of origin, an economic instrument could help to achieve this goal. For instance, social security taxes could be refunded when migrants returned home, encouraging voluntary returns.

On the other hand, this proposal is only feasible if there were viable and sustainable options for their return and reintegration (access to employment and income). As mentioned before, migration flows of unqualified workforce are caused by the lack of economic opportunities in their region of origin. In these regions the diversification of income and employment opportunities (both agricultural and non-agricultural) in rural areas has to be promoted through specific policies and programs.

Agricultural programs

- Strategies to foster food production. An alternative could be to develop a strategy in which farmers would have access to land. The strategy implementation could at first concentrate on a small number of easily merchantable and profitable strategic food crops. Nevertheless, there is the possibility that some regions will not have a ready market to absorb increased agricultural production. In such cases, the Brazilian Government could be involved in the promotion of trade (expanding markets through economic integration, supporting their participation in national value chains) and/or provision of purchase guarantees. This strategy would require a previous planning of the supply and demand of the crops targeted to be produced. In addition, it would be ideal to carry out their selection based on their suitability to grow on specific conditions (e.g. soil quality, terrain and weather conditions). In such way these lands would not only remain being subsistence oriented, but will produce crops that will increase the food security of their region.

On the other hand, in order to foster an effective implementation of this proposal, it will be necessary to tackle fundamental challenges through additional strategies: (i) farmers should receive training on diverse crops and best agricultural practices, (ii) basic infrastructure requirements must be satisfied.

Regarding the application of good agricultural practices, training programs should be developed with the objective of raising land productivity considering the choice of inputs, the use of appropriate technology, tillage and crop rotation practices.

Challenges associated with deficiencies of rural infrastructure are especially important. These regions have to be provided with basic infrastructure (such as storage houses) but also transport and connection to major roads.

The organization of these food producers could increase their bargaining power as consumers of agricultural inputs and sellers of products.

Non-agricultural programs

To foster off-farm activities in the rural areas (of origin) could be an alternative to alleviate migration pressure. Various approaches could be taken in order to generate employment and income opportunities, for instance: (i) to foster the development of small enterprises based on agricultural activities, (ii) to directly support already existing micro and small-scale local enterprises with technical advisory services and capacity building.

The agricultural sector is linked to potential job generation areas such as agro-processing besides other services. Projects could be developed using a fund scheme to finance promising small industries such as fruit and vegetable processing, production of juices, sweets, pulps, etc. Access to micro credits on competitive terms could foster the investment of local populations in agricultural and off-farm income generation activities. For both alternatives (agricultural and off-farm activities) skill development in rural areas could be achieved through rural extension services and technical training programs. In addition, public and private labor intermediaries could also help to better match the supply and the demands sides of newly developed markets.

Final remarks

Unemployment associated with the demand reduction of manual sugarcane harvesters will affect mainly the unqualified migrant workers. The real complexity of this problematic relies in the sharp regional social and economic differences in Brazil which have led to the migration of large amounts of unqualified migrants to other regions. The impacts of the proposed and other existing policies and programs (such as Bolsa Familia) developed to reduce migration pressures should be evaluated. Migratory flows could be monitored and measured, and even when it will take long time to carry out such controls, the policies targeted on specific regions and migration-prone groups could be evaluated. On the other hand, basic education might be a challenge for programs aimed at improving skills and knowledge in rural areas. Furthermore, education will also be crucial for the workers to entry into the non-farm economy. The Brazilian Government should continue fostering better access to education (and also skills upgrading) with a special focus in rural areas. In addition, when considering the improvement of life conditions in rural settings it is also important to set priorities regarding access to adequate health services, water and sanitation and infrastructure. In conclusion, it would be necessary that the Brazilian Government integrates specific rural concerns into national policies and plans (e.g. increasing investment in public goods and services) in order to reverse its declining trend.

Financing

It is important to note that the implementation of such strategies would require a substantial amount of resources (capital investment) and good governance. The roles and responsibilities of the involved partners should be defined as the strategy is developed.

Qualification efforts in sugarcane producing regions can be implemented with the establishment of cooperation links between financial institutions and enterprises. For instance through attractive credit terms, or with schemes in which investments in qualification could be deducted from the tax collection.

On the other hand, the state governments of deprived regions might encounter limited capital for the proposed developing projects. In this case, their implementation would depend on the Government of Brazil and its will and leadership to make from these projects a priority.

A question would be if market instruments could help to finance the qualification strategy objectives when environmental and labor laws were disrespected. In this way it would be insured that legal frameworks are geared towards stimulating environmental and social sustainability. Nevertheless, it is important to bear in mind that such fines would not be enough to finance these measures.

Rough estimations

It is important to note that trying to quantify the specific needs of the proposed qualification programs (the exact number of workers to be qualified, their characteristics and the costs) is a difficult task. As it was shown along this dissertation, the developments of the Brazilian sugarcane agro-industry will be determined by a complex set of interactions among a number of influencing factors. Nevertheless, it is possible to grasp rough estimates.

UNICA (2010) forecasted that by the 2015/16 harvest (when 100% of the sugarcane in areas suitable for mechanization will be collected mechanically) there will be ca. 59,500 workers occupied in mechanical harvest operations only in Sao Paulo state.

In 2010/11 there were already 30,800 workers occupied in mechanical harvest operations. This would mean that in 5 years (from 2010/11 to 2015/16) there will be the need to qualify (or recruit) 28,700 extra workers (ca. to double the qualified workers during the considered period).

On the other hand, during the 2010/11 harvest, there were 107,400 workers occupied in manual harvest. The number of workers will be virtually reduced to zero by 2015/16. Therefore, even when 100% of the qualified workers required by the sector in 2015/16 were current manual harvesters, there would be a surplus of 78,700 workers that would not have chances to be reabsorbed into sugarcane agricultural activities.

According to Aguiar et al. (2011), in Sao Paulo state for the 2010/11 harvest 2,627,023 ha of sugarcane were harvested mechanically, while 2,101,110 ha were harvested manually. When considering the employment figures from UNICA (2010) the amount of workforce demanded for each 100 ha would be 1.2 for a mechanized scenario and 5.1 for a manual scenario (Table 34).

Table 34: Estimation of the workforce ratio based on the figures from Sao Paulo in the harvest 2010/11

Mechanized Scenario			**Manual scenario**		
Hectares harvested(1)	Number of workers(2)	Workforce ratio*	Hectares harvested	Number of workers	Workforce ratio*
2,627,023	30,800	1.2	2,101,110	107,400	5.1

Source: Aguiar et al. (2011) (1), UNICA, 2010(2)
Note*: men/100 ha

It is interesting to note that the figure of the workforce ratio obtained for the mechanized scenario varies much in comparison to the IEA (2009) estimation (8 men/year for each 100 ha under current mechanization conditions). This could be partially explained because the workforce figures of IEA do not only involve the workers directly associated with the harvest activities but also take into consideration all the other agricultural occupations.

Carrara (2009) also took into consideration all the agricultural occupations of the sugarcane production in a case study mill in Sao Paulo and concluded that the ratio of workers in a mechanized and manual scenario was 1:6 (in 24 hours) (Table 6). From the values obtained, the ratio of workforce demand of mechanical harvesting and manual harvesting is 1:4.25.

These figures could only provide rough hints about the qualification needs of other regions, the exact number of workers occupied in mechanization/manual sugarcane activities will depend on the developments in land expansion, production, and technology adopted.

Characteristics

When developing the qualification programs, it will be important to take into consideration the specific characteristics of the target group (sugarcane manual harvesters).

According to PNAD, in 2008 in Sao Paulo the average years of schooling of sugarcane agricultural workers were 5.4 (Moraes et al., 2011). This figure includes: non-specialized agricultural workers, workers occupied in mechanization and other agricultural activities.

When disaggregating these occupational categories, according to CAGED, in 2008 from the total number of admissions of sugarcane agricultural workers: mechanization workers accounted for 5.40%, 91.45% were non-specialized agricultural workers and 3.13% were other agricultural activities. For this same year the largest proportion of non-specialized agricultural workers (28.9%) did not complete the 4^{th} series while the largest proportion of mechanization workers (22.4%) completed the second degree (Fredo, 2011).

Ideally, the courses should be developed sorting the workers by their educational level.

On the other hand, one difficulty to be tackled by the proposed program will be the regional differences of the formal education. According to PNAD, the average of schooling years in 2008 in the North and Northeast regions was only 3.1 (Moraes et al., 2011).

Costs

In order to estimate the costs of the proposed initiative, it is possible to use the costs of the Sugarcane Agro-industry National Qualification Plan as baseline. According to the MTE, the total budget of the program for 2010 was:

R$ = R$ 5,757,816

which should have benefited:

X= 6,603 workers

Therefore, the maximum limit per worker in this plan is R$ 872.

The average number of hours per course is:

Y = 200

Based on these values, the average cost per worker/hour is

Z = R$/(X*Y)

Z = R$4.3

Even when these figures and strategies can provide an indication of how the proposed strategies can be managed, the real investment cost will depend on the scope and specific characteristics of the program. For instance at UNICAMP a specialization course that has 360 hours costs ca. R$9,000 (Z = R$25 worker/hour) (Walter, pers. comm., 2012).

The Sugarcane Agro-industry National Qualification Plan is financed 95% by the Ministry of Employment and (minimum) 5% by the proposing entity. On the other hand, the RenovAcao program of UNICA received funding from industry participants such as Syngenta, John Deere and Case and support from the Inter-American Development Bank. A similar scheme could be used for the proposed strategy.

8.2 General conclusions

The sugarcane agro-industry in Brazil has a strategic importance given the significance of its main products: sugar and ethanol. The mechanization of the sugarcane harvesting will have economic, environmental, agronomic and social impacts. From the economic point of view, cost reductions, and possibly higher productivity can be expected. Furthermore, mechanization could have a positive impact on the environmental dimension of the sector's sustainability as it avoids the need for pre-burning practices. This point is especially relevant for the ethanol supply chain.

As mechanization enables the harvest of raw sugarcane, dry leaves and tops (trash) are left on the field which could have agronomic advantages. In addition, the recovery of a reasonable fraction of the total amount of sugarcane trash could have a large potential for bioelectricity applications when processed with efficient power technologies. These energy gains could increase the sector's competitiveness and in some extent avoid emissions that otherwise would have been produced from fossil fuels in thermal power plants.

The Brazilian sugarcane agro-industry has succeeded in producing more efficiently while becoming more environmentally compatible at the same time. Nevertheless, the sector now faces the challenge (and the opportunity) of conciliating the modernization of its agricultural sector with a socially sustainable transition.

The main outcome of this dissertation was a set of policy recommendations aimed at both: (i) to guarantee that the requirement of the enterprises in terms of qualified workforce will be satisfied in the most sustainable way from a social point of view, and (ii) to mitigate the impact of the unemployment associated with the demand reduction of manual sugarcane harvesters.

It is important to bear in mind that the labor market dynamics of the sugarcane agro-industry in Brazil are largely influenced by the regional differences of the country. These differences are deeply rooted in entrenched historical and cultural patterns that will be difficult to change.

Therefore, the problem addressed within this Ph.D. thesis is also related to a more general and complex problem. This problem requires a wide-raging approach and ambitious actions aimed at bridging socioeconomic inequalities in the country.

The construction of a framework based on the Human Capability Framework (NZDoL, 1999) facilitated a robust and systematized analysis of capacity and labor market influencing features. The applicability of the HCF as a research tool based on stakeholder's interaction and feedback was proven. Using the framework enabled the consideration of the role of various interest groups at local and regional levels. One of its advantages is that it allows the isolated study of the factors influencing both sides: capacity and opportunity. On the other hand the HCF also supports the explanation of the cause and effect relationships so that they can provide a rationale for developing a subsequent strategy. It was concluded, that the HCF could be a valuable tool to address complex problematic characterized by the confluence of several influencing factors.

The development of policy recommendations was based on the analysis of the capacity and labor market influencing features and their matching process. Key conclusions of these analyses are summarized in the Tables 39 and 40.

Table 35: Summary of the capacity influencing features

Background
• Migration is largely caused by general economic stagnation, lack of employment opportunities and low income in the regions of origin. **Challenges** • There is a trend in producing regions to hire fewer migrants giving priority to locals, as possible. • Migrants are not eligible for most of the qualification efforts in the producing regions. • Migrants will have difficulties to relocate in their region of origin if dismissed from the sector. If they did, they would have difficulties to find a comparable job in terms of remuneration. • There will be negative impacts in the regions of origin when stopping receiving the income of the migrants (which should have in some extent contributed to develop consumer market). • An unknown share of these workers would continue migrating to other regions even after being dismissed from the sector. **Opportunities** • Public policies developed targeting their regions of origin could at least partially control the migration flows.
Workers' union affiliation
Depending on the degree of organization of the syndical movement, they could have diverse degrees of influence when dealing with the new labor market arrangements. **Opportunities** • Workers' unions could support the implementation of strategies to solve the problematic (active involvement in qualification programs). • The role of the workers' unions will be important to negotiate not only the work conditions of the specialized workers, but also those of the manual harvesters that will remain in the sector.
Informal skill formation
Opportunities • Given their background, rural workers could be able to perform in farm settings if fundamental challenges were tackled through strategies such as: (i) training on diverse crops and best agricultural practices, (ii) providing basic infrastructure requirements.
Formal skill formation
Challenges • The sector's rural workforce is characterized by low education levels which will hinder

their reabsorption in the agro-industry or any other sector, including agriculture (due to the increasing mechanization trend).

Opportunities

- The development of a rural alphabetization strategy focused on the deprived areas of the country could improve this situation. These strategies should be focused in being accessible for the targeted groups.

Demographics

- There is a decreasing trend of women participation in the agricultural occupations of the sector.
- There is a trend to retain young workers for carrying out agricultural jobs.

Opportunities

- Positive discrimination strategies could foster the integration of vulnerable groups such as women and aged agricultural workers through promoting their access to qualification programs.

Productivity

- Higher productivity of the workers increases their perspectives of remaining in the sector. Whether they will remain carrying out non-specialized agricultural activities or will be benefited from a qualification initiative, has to be decided under standardized basis.

Opportunities

- Upgrading qualification strategies could also improve their perspectives for occupational development.

Table 36: Summary of the labor market influencing features

National and international markets

- There is an increasing influence of globalization on the developments of the sugarcane agro-industry. National and international demand for ethanol and sugar influence its expansion.
- As new markets are being developed sustainability standards might have to be implemented influencing positively the work conditions and labor relations.

Legislation

- Rural workers are well provisioned under labor laws. Nevertheless, this does not imply that such laws will be respected. Enforcement will continue to be a key strategy for the sector.
- Environmental laws will impact the timeframe in which the mechanization will occur in specific producing regions.

Opportunities

- Market instruments could help to finance the solutions / strategies objectives when environmental and labor laws were disrespected.

Agricultural trends

- There is an increasing trend for expanding the area and augmenting the production of sugarcane. Nevertheless, these trends are not necessarily linked to an increase of workforce demand. On the contrary, there is trend for reducing the workforce intensity.
- The expansion of the sector has in some extent compensated the reduction of workforce.
- The demand of workforce will \depend on the developments in planted area, production and productivity.

Challenges

- The land competition with other mechanized crops in the expansion area could also create competition in the market of specialized workforce.

Working conditions

- Improvements in the working conditions in the sector have been acknowledged.
- The working conditions of the sector are heterogeneous. Including (even when isolated) cases of serious law violations (such as slavery).

Opportunities

- The improvement of work conditions could improve the international market perspectives of producing units.

The pace of mechanization

- The type of technology adopted and the rate in which it is implemented will define the number and the pace in which the workers will be demanded.

Challenges

- If the pace of mechanization is too fast, there might not be time for the industry to react and qualify the specialized workers demanded. Furthermore, the rate in which non-specialized workers are dismissed will also increase and there will be no time to introduce compensatory public policies.

Opportunities

- The ideal case would be to harmonize the public policies / strategies implementation with the pace in which mechanization is adopted. In order to achieve this, the coordination of social and environmental laws could be an option (burning phasing out calendar coordinated with social strategies).

Ago-environmental Zoning

- It is expected to steer the geographical allocation of the sector's expansion and therefore the allocation of its workforce.

Opportunities

- Market instruments could help to finance the solutions / strategies objectives when environmental and labor laws were disrespected.

8.3 Strategic axis of intervention (illustration)

Based on the figure 60, the strategic areas of intervention proposed by this dissertation are illustrated in the Figure 62. These actions aim to break the loops that would result in undesirable consequences.

1) The qualification programs developed at the sugarcane producing regions are expected to tackle the lack of qualified workers in the sector. The qualification programs should take into consideration the environmental legislation and protocols banning the sugarcane burning and the Agro-environmental zoning. In this way, it will be possible to predict when, where and how big will the demand for qualified workers be. As mentioned before, it would also be ideal to coordinate the qualification and the legislation agendas.

2) In order to foster a sustainable transition in social terms, the qualification programs aim to reabsorb as many workers as possible within the sector. Therefore, it is important to give priority to the surplus non-specialized workers collaborating already in the industry. Positive discrimination strategies could help to achieve this aim.

3) Besides labor market programs, there is also a proposal for the development of non-labor market strategies in order to minimize the effects of unemployment of non-specialized workers. It will also be necessary to foster economic activities that could absorb these workers.

4) On the other hand, the possibilities of the rural workers to be absorbed into other economic sectors would increase if there was a stronger focus on the rural basic education.

5) The agricultural and non-agricultural programs in the migrant's regions of origin are expected to foster their development through reducing emigration pressure. The agricultural strategies proposed are mainly related to food production goals.

The expected outcomes of the proposals developed are illustrated in the Figure 73. These outcomes are: (i) to mitigate impacts of unemployment, (ii) to satisfy the sector's requirements by avoiding the reduction of the pace of mechanization, reducing costs, etc., and (iii) to reduce migration flows. The ultimate objective of these strategies is to constructively link the energy, environmental, economic and social sustainability objectives of the Brazilian sugarcane agro-industry through the mechanization of the harvest.

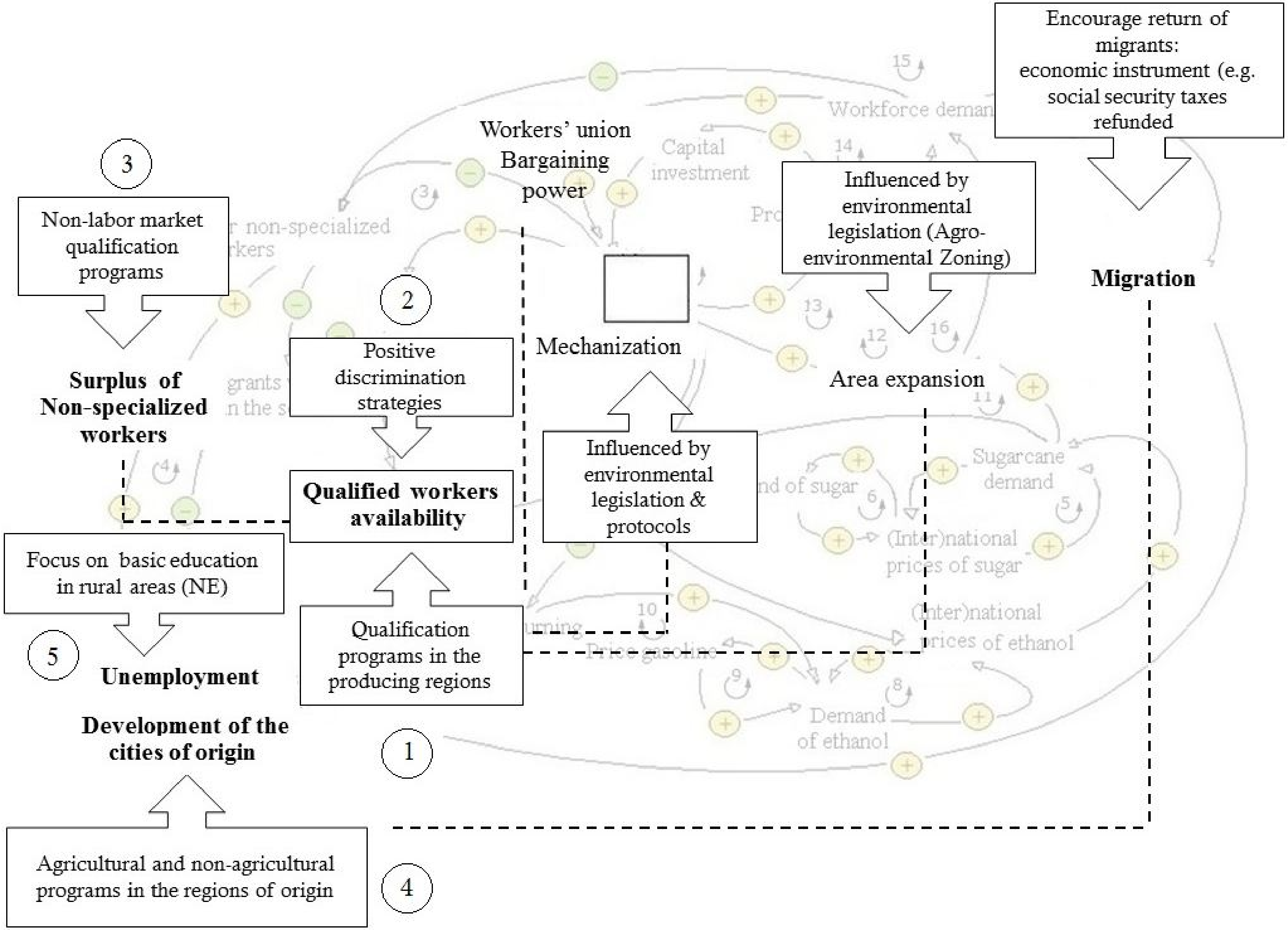

Fig. 62: Strategic areas of intervention

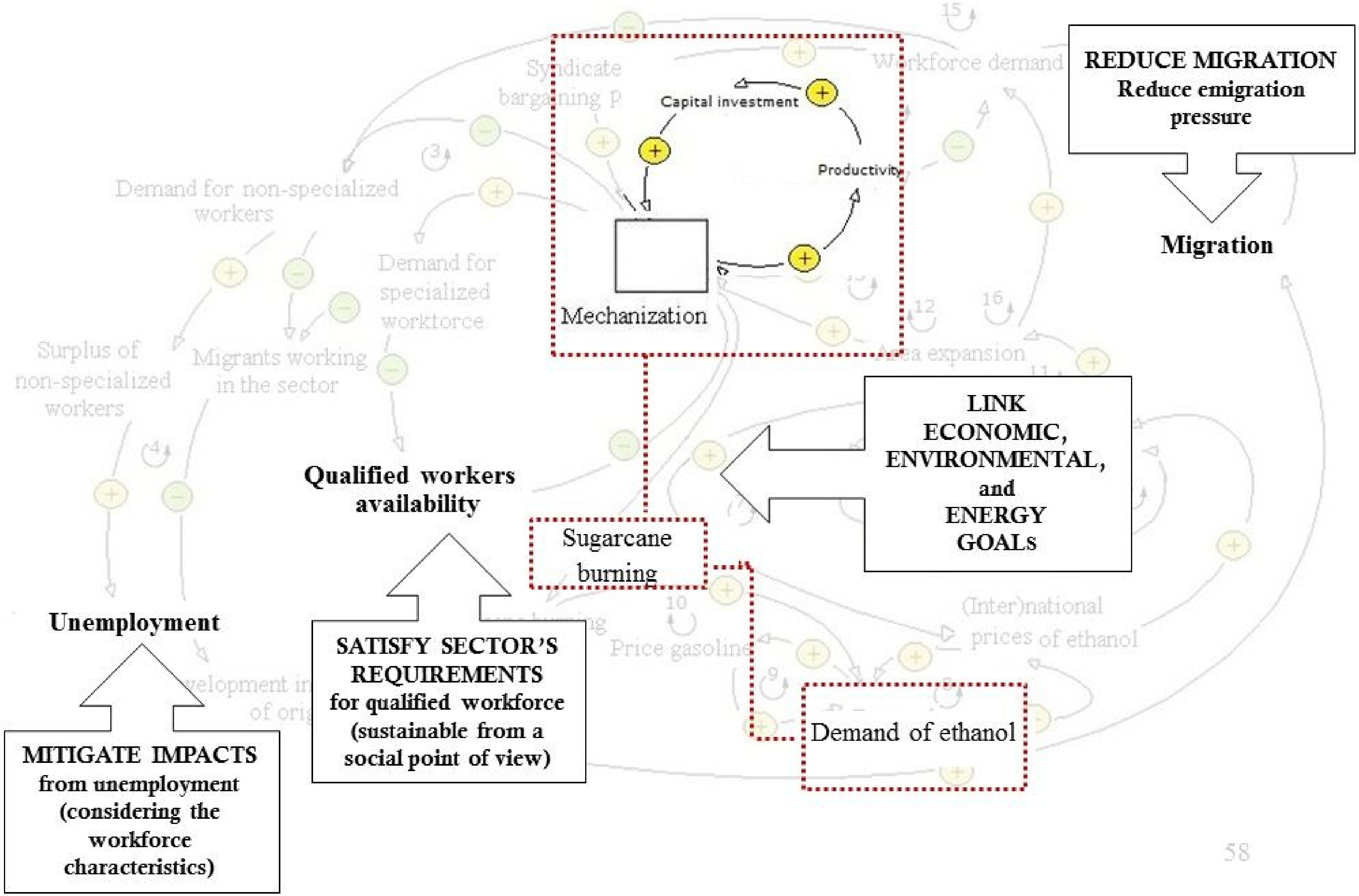

Fig. 63: Expected outcomes

8.4 Further research work

From the results of this dissertation and its limitations, possibilities for complementary research works arise.

One relevant topic could be to monitor the outcomes of the qualification strategies currently adopted by the sector.

Another interesting topic would be to analyze the perspectives of other specific sectors (e.g. civil construction) to compensate the unemployment caused by the demand reductions of non-specialized agricultural workers.

Furthermore, the development of econometric models trying to identify the marginal contribution of diverse influencing factors of the mechanization adoption could at least provide a reference on future developments.

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ANNEXES

1) Brazil's Political Division

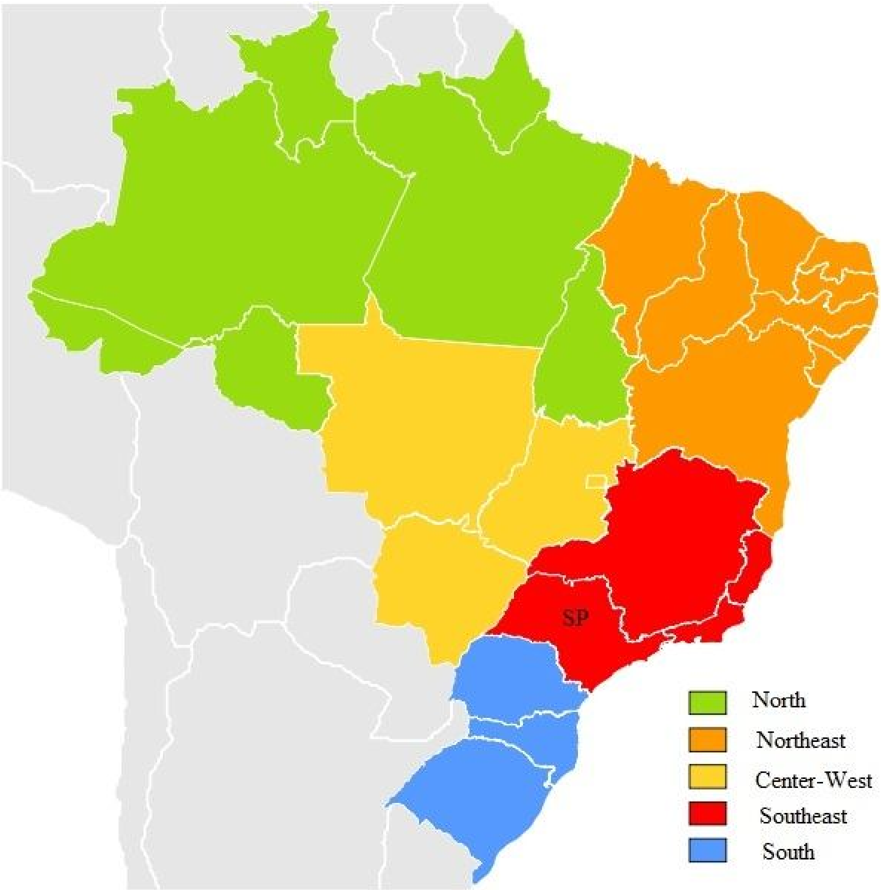

Fig. 64: Brazilian macro-regions
Source: Menegaz, 2007

According to IBGE (2012), Brazil is divided into five macro-regions:

North region: Acre, Amapá, Amazonas, Pará, Rondônia, Roraima, Tocantins

Northeast region: Alagoas, Bahia, Ceará, Maranhão, Paraíba, Pernambuco, Piauí, Rio Grande do Norte, Sergipe

Center-West: Goiás, Mato Grosso, Mato Grosso do Sul, Distrito Federal (Federal District).

South-East region: Espírito Santo, Minas Gerais, Rio de Janeiro, São Paulo

South region: Paraná, Rio Grande do Sul, Santa Catarina

2) General structure of the interviews to stakeholders

- Which are the most important impacts of the mechanization of the sugarcane harvest? (in general)
- Which are the most important impacts of mechanization in the workforce?

- Which aspects do you think that will drive the developments of the sector and why? (occupation side of the Framework)
- Which aspects do you think that will enable the workers to stay in the sector after mechanization and why? (capacity side of the Framework)
- Which are the challenges of the sugarcane agro-industry due to the mechanization of the harvest?
- Which are the opportunities of the sector?
- How do you think the problem could be solved?

3) Questionnaires applied to industrial and agricultural managers

- How many sugarcane tons/year does your mill process?
- How many workers are there employed in your sugarcane mill?
- How many workers are linked to the production of sugar, sugarcane and alcohol?
- Which proportion of the jobs of your sugarcane mill is temporary?
- In average, how many sugarcane tons are harvested manually per worker?
- How much is the average daily salary of the manual sugarcane harvesters?
- Which percentage of the total sugarcane manual harvesters employed in your company are migrants?
- Does your company pays different tariffs depending of the difficulty degree of the sugarcane harvested?
- In which percentage is the harvest mechanized?
- How much is the salary of the operator of a mechanical harvester in comparison with a manual harvester?
- When using mechanical harvesters, are you still burning the fields previously?
- How has been the evolution along time of the total manual workers?
- Does your sugarcane mill have qualification programs?
- Is the planting operation also mechanized?